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CONTROL OF OIL AND OTHER HAZARDOUS MATERIALS

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CONTROL OF OIL AND OTHER HAZARDOUS MATERIALS

This course is offered for employees of regulatory agencies who are assigned direct responsibility for response to nonrecurring discharges of oil. It is not intended to dictate arbitrary solutions to technical problems in spill control but will familiarize students with alternatives and provide opportunity to practice response under realistic constraints and measures of success. In particular, students who complete this course will be able to function within the guidelines of Federal, State, or interstate Contingency Plans in effect in the area where the course is presented.

ENVIRONMENTAL PROTECTION AGENCY
Water Program Operations
TRAINING PROGRAM

June 1974

FOREWORD

These manuals are prepared for reference use of students enrolled in scheduled training courses of the Water Program Operations, Environmental Protection Agency.

> *Due to the limited availability of the manuals, it is not appropriate to cite them as technical references in bibliographies or other forms of publication.*
>
> *References to products and manufacturers are for illustration only; such references do not imply product endorsement by the Office of Water Programs, Environmental Protection Agency.*

The reference outlines in this manual have been selected and developed with a goal of providing the student with a fund of the best available current information pertinent to the subject matter of the course. Individual instructors may provide additional material to cover special aspects of their own presentations.

This manual will be useful to anyone who has need for information on the subjects covered. However, it should be understood that the manual will have its greatest value as an adjunct to classroom presentations. The inherent advantages of classroom presentation is in the give-and-take discussions and exchange of information between and among students and the instructional staff.

Constructive suggestions for improvement in the coverage, content, and format of the manual are solicited and will be given full consideration.

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HAZARDOUS SUBSTANCES DISCHARGE PROBLEMS

I MAGNITUDE OF THE HAZARDOUS SUBSTANCES DISCHARGE PROBLEM

A Worldwide

It has been recognized since the late 1800's that water pollution has grown in scope from a national problem to an international one. The volume of waste materials dumped into the ocean is growing rapidly. Because the capacity of land-based waste disposal sites is becoming exhausted in some cities, communities are looking to the ocean as a dumping ground for their wastes. A massive increase in the already growing level of ocean dumping could cause widespread environmental deterioration. Therefore, the Council on Environmental Quality has recommended a comprehensive national policy to ban unregulated ocean dumping of all materials and strictly limit ocean disposal of any materials harmful to the marine environment. With waste disposal sites becoming exhausted on land and regulated in oceans, the only remaining United States environmental sites, other than air, are its navigable waters.

B Navigable Waters of the United States

For the purpose of this hazardous substances training course, only pollution of the navigable waters of the United States by hazardous substances (other than oil) shall be considered to be the problem.

C Types of Substances Discharged

Discharges of hazardous substances reported to the Division of Oil & Hazardous Materials, Water Quality Office, Environmental Protection Agency, show that the nature of the substances reported ranged from inorganic to organic, acids to bases, elements to complexions, pesticides to cyanides. Some substances have made their presence first known in the water by a resultant fish kill.

Other substances having characteristics of flammable materials, compressed gases, corrosive materials, explosives, oxidizing agents, poisons, and cryogenic materials can be hazardous to public health or welfare.

D Understanding the Magnitude of the Problem

To aid in understanding the magnitude of the problems of continuous and noncontinuous discharge of hazardous substances, the following examples may be used. Eighteen aromatic organic chemicals were produced in 1970, with the yearly production being approximately eleven million tons. If the manufacturing process is 90% efficient, then potentially more than 1 million tons of these chemicals or other production products or intermediates could be continuously discharged into the water environment. If 90% of this yearly production from eighteen chemicals were treated before discharge, there would still be a yearly discharge of 100,000 tons into the water environment. To further magnify the problem, there are four and one-half million chemicals which are potential candidates for being hazardous polluting substances of navigable waters of the United States.

Three popular sizes of tank barges can carry maximum capacities of 1000, 1500, and 3000 tons of liquid. Ninety-four accidents are predicted for domestic water carriers of hazardous substances other than oil this year. Therefore, if the total hazardous substance cargo of one of the smallest barges, if lost in an accident, the least amount of hazardous substance entering the navigable waters this year from barge accidents could be about 94,000 tons. Some examples of substances which are shipped by this mode are acetone cyanohydrin, acetonitrile, anhydrous ammonia, carbon disulfide, epichlorohydrin, freon and haphthalene.

II RATIONAL FOR THE DISTINCTION BETWEEN OIL AND HAZARDOUS SUBSTANCES

Figure 1 illustrates the decision points that may be used to discriminate between an "... oil of any kind in any form ..." and a material which may be considered to be designated a hazardous substance. This distinction implies that a material determined not to be an oil need not be a hazardous substance. This flexibility must be provided since not all non oil materials are necessarily hazardous substances.

The rational involved with Figure 1 requires that at least three questions be answered for most materials. Is the material in question derived from a petroleum or petroleum-like source? If the material is petroleum derived, is the chemical structure defined? If the chemical structure is not defined for this petroleum derived material, then it is an oil and can occur in any form.

However, if the material is not derived from a petroleum or petroleum-like source, then is the material extractable by an organic solvent such as benzene, chloroform, or carbontetrachloride? If the non petroleum derived material is extractable by an organic solvent, there again the question of chemical structure being defined must be asked. If the chemical structure of the extractable non petroleum derived materials is not defined, then it is an oil of any kind. If the non petroleum derived material which is extractable has a defined chemical structure, it is a candidate for designation as a hazardous substance. The last alternative is that of a non petroleum derived material which is not extractable by organic solvent. This material may be a candidate for designation as a hazardous substance and would include a multitude of elements and compounds and mixtures thereof. To test the rationale, examples are provided in Table 1.

III TYPES OF DISCHARGES

A Discharges of hazardous substances are of two types:

1 Continuous discharge

2 Noncontinuous discharge

B A continuous discharge is one in which the material is discharged without ceasing or is discharged in a continuing pattern or schedule.

C A noncontinuous discharge is one which is unscheduled and which ceases.

Thus it is a probabilistic problem.

IV REASONS FOR INCREASED HAZARDOUS SUBSTANCES DISCHARGE INTO NAVIGABLE WATERS OF U.S.

Some of the reasons for the increased discharge of hazardous substances into the navigable waters of the United States are as follows:

A The ten year projected growth rate of hazardous materials productions appears to be one and one-half times that of the Gross National Product growth rate.

B Total hazardous material quantities transported are projected to increase by almost 55% during the next ten years.

C Hazardous materials are comprising an increasing proportion of total intercity freight traffic.

D There has been an increase in the number of total accidents and of those in which hazardous materials were present. Projections to 1980 indicate continued increases.

E Larger unit packages and larger groupings of unit packages of hazardous materials indicate a resultant increased severity of disaster.

F Due to increased production of commercial products, there is an increase in the amount of continuous discharge of hazardous substances.

G Not only does the Gross National Product growth rate increase indicate increases in hazardous substances discharge, but when economic conditions cause a decrease in the Gross National Product, it is reasonable to assume that there would also be an increase in hazardous substances discharge because normal operating conditions would be changed or curtailed, personnel responsibilities increased while the work force is static or reduced and, in general, the situation would be more conducive to hazardous substance discharge than in a more stable operating routine.

This outline was prepared by C. H. Thompson, Chief, Hazardous Materials Branch, Division of Oil and Hazardous Materials, Environmental Protection Agency, Office of Water Programs, Washington, DC 20460.

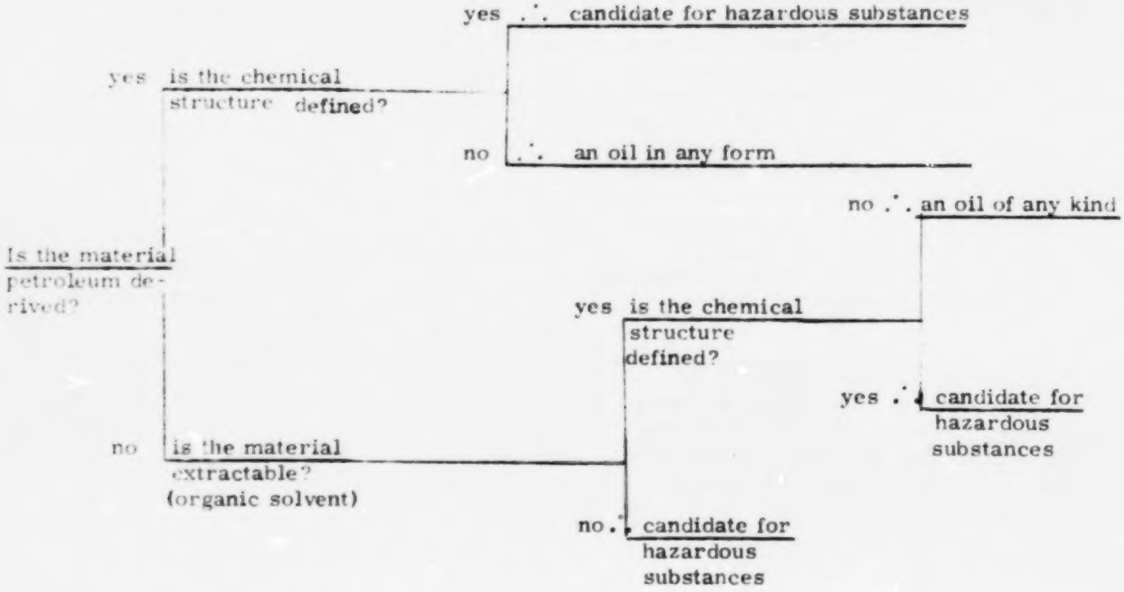
Is the material petroleum derived?
yes
is the chemical structure defined?
yes .˙. candidate for hazardous substances
no .˙. an oil in any form
no
is the material extractable? (organic solvent)
yes
is the chemical structure defined?
no .˙. an oil of any kind
yes .˙. candidate for hazardous substances
no .˙. candidate for hazardous substances

FIGURE I

RATIONAL FOR DISTINGUISHING BETWEEN OILS AND MATERIALS THAT MAY BE HAZARDOUS SUBSTANCES

TABLE 1

EXAMPLES OF MATERIALS TO TEST THE RATIONALE TO DISTINGUISH BETWEEN OILS AND POSSIBLE HAZARDOUS SUBSTANCES

Materials	Petroleum Derived	Chemical Structure	Extractable (Solvent)	Chemical Structure	Oil/ Haz. S
Crude Oil	Yes	No	--	--	Oil
JP-4 Fuel	Yes	No	--	--	Oil
Toluene	Yes	Yes	--	--	H. S.
Tallow	No	--	Yes	No	Oil
Molasses	No	--	No	--	H. S.
Refinery Waste	Yes	No	--	--	Oil
Plating Waste	No	--	No	--	H. S.
Mix - Kerosene & Benzene	Yes	No	--	--	Oil
Corn Oil	No	--	Yes	No	Oil
Stearic Acid	No	--	Yes	Yes	H. S.
Meat Renderings	No	--	Yes	No	Oil
Coal Dust	Yes	No	--	--	Oil
Cresol	Yes	Yes	--	--	H. S.
Whale Oil	No	--	Yes	No	Oil
Hexanol	Yes	Yes	--	--	H. S.
Lacquer Based Paint	No	--	Yes	No	Oil
Methyl Mercury	No	--	Yes	Yes	H. S.
DDT	Yes	Yes	--	--	H. S.

GENERAL INFORMATION ON EFFECTS, CAUSES AND CONTROL OF HAZARDOUS MATERIAL SPILLS

I INTRODUCTION

More than two billion tons of potentially hazardous materials were produced and handled in the United States during 1968-1969. It is projected that the annual production quantities of these materials will approximate four billion tons in 1980. Over 70 percent of these quantities are transported by motor truck, railway, water barge and pipeline. As long as the tonnage of liquid, solid and gaseous hazardous chemicals produced, handled, and transported by our land and waterways continue to follow the present upward trend, the accidental spillage of these materials poses a real and growing threat of pollution to our watercourses.

II EFFECTS

The effects of these materials on watercourses and the plant and animal life associated with them may vary widely. In general, most chemicals, when present in the environment above certain critical concentrations, are toxic to biological life and detrimental to the environment's aesthetic quality. Although many substances are obviously hazardous to aquatic and marine life due to direct acute toxicity, other substances are equally detrimental to water ecosystems by virtue of indirect toxicity resulting from depletion of the dissolved oxygen supply required to support various life forms. Still others, although originally present at less than toxic or inhibitory levels, may become concentrated to these levels by residual accumulation through a succession of food chain transfers. In addition to direct effects of the spilled hazardous materials, there may be other effects of the products of reaction between the pollutant and water or other materials in the watercourse. Our present knowledge of the adverse effects of a particular spill on the environment, especially the persistence of the spilled material and its immediate and long term effects, is very limited.

III CAUSES

A General

The accidental entrance of a hazardous material into a watercourse can occur in a variety of ways. Spills or sudden discharges can result from mechanical malfunction, collision, fire or human error in connection with rail, highway and water modes of transportation or with stationary sources such as manufacturing or storage facilities. The most serious type of spill occurs when a container is violently ruptured and large quantities of the hazardous material are spilled almost instantaneously. In some cases, the material may be discharged directly into a watercourse, while in others the spilled material may flow or be washed into sewers, drainage channels or percolate slowly into ground water supplies.

B Transportation Sources

A significant portion of the total problem of hazardous material spills is caused by transportation accidents. While derailment presents the major potential for railroad tank car spills, collision and sinking are obvious sources of barge spills. Spills may also occur at tank truck, tank car and barge loading/unloading facilities due to defective transfer pump and flange connections, hose failures and valve packing and seal deficiencies.

C Stationary Sources

1 One of the largest single sources of pollution incidents in industrial plants is failure or breakdown of manufacturing or process equipment. These failures include broken pipelines in chemical plants, leaking tanks, malfunction of refrigeration equipment, overflowing of chemicals from tanks during

manufacture, faulty pressure gauges and valves, pump breakdown, operational errors, metal failure due to corrosion in acid transport pipes, explosions and fires. These sources of pollution incidents are compounded to some degree by the many intentional discharges of unwanted hazardous materials into our nation's waters.

2 Storage facility spills also contribute to the overall problem. Numerous fish kills result from leaks from storage tanks and broken lagoon dikes. The leaching action of rain water on open stockpiles of hazardous chemicals stored in the open at water edge locations has also greatly added to the contamination of our waterways.

IV CONTROL

A Prevention

It is generally agreed that the prevention of hazardous material spills constitutes the most desirable method for effective water pollution control. Unfortunately, previous efforts to provide adequate safeguards for handling these materials and for preventing their release into the aquatic environment have not been very successful. A recently completed study (1), initiated by EPA's Office of Oil and Hazardous Materials (Water Quality Office), concluded that there are presently no uniform industry-wide standards in the United States for spill prevention and, consequently, preventive techniques, equipment and operational procedures need to be developed to protect the public health and welfare.

B Countermeasures

1 Although prevention remains the first and most important line of defense, it must be recognized that even with the most comprehensive precautionary techniques, accidents involving the uncontrolled release of detrimental substances to the environment must be anticipated and appropriate response measures must be developed to minimize undesirable ecological effects. Existing countermeasure techniques have been developed primarily for continuous discharge waste treatment systems under controlled conditions. However, because of the rapid response required in the case of spills, the majority of these available techniques are not satisfactory for application in the aquatic environment.

Hazardous materials involved in spills which enter a watercourse may be categorized on the basis of their densities and solubilities in water. The heavier, insoluble materials such as ethylene dichloride and sulfur will sink to the bottom of waterways. The removal of these contaminants by physical means, such as suction or dredge type devices, is a possibility. Less dense water insoluble chemicals such as decyl alcohol will tend to float. The mechanical separation of these materials by confining the spill to a small area by booms and removing the materials by skimming should be relatively successful. In the case of water soluble materials such as phenol and acrylonitrile, mechanical means of removal are no longer possible since the spilled material will be in solution.

2 Priority ranking system

Because water soluble chemicals present the greatest threat to the water ecosystem from a countermeasure point of view, a priority ranking system for estimating the theoretical inherent hazard of these chemicals was prepared as part of an EPA sponsored state-of-the-art study (2) on hazardous material spills. The ranking system is based on (a) the lowest concentration range at which a material impairs any of the beneficial uses of water, (b) the quantity shipped annually by each mode of transport and (c) the probability of an accidental spill to surface waters for each transport mode. Since a material's ranking is then representative of its potential threat to water quality, it is expected that this system should provide the guidelines for determining which chemicals receive the greatest attention relative to the development of spill countermeasure techniques.

To illustrate this ranking system, the top twenty water soluble substances are arranged in order of decreasing priority in Table 1.

TABLE 1
PRIORITY RANKING OF SOLUBLE HAZARDOUS SUBSTANCES

Rank	Substance
1	Phenol
2	Methyl Alcohol
3	Cyclic Rodenticides
4	Acrylonitrile
5	Chlorosulfonic Acid
6	Benzene
7	Ammonia
8	Misc. Cyclic Insecticides
9	Phosphorous Pentasulfide
10	Styrene
11	Acetone Cyanohydrin
12	Chlorine
13	Nonyl Phenol
14	DDT
15	Isoprene
16	Xylenes
17	Nitrophenol
18	Aldrin-Toxaphene Group
19	Ammonium Nitrate
20	Aluminum Sulfate

These substances include both organic and inorganic materials and range from solids to liquids to gases under standard conditions of pressure and temperature.

3 Defensive and offensive measures

The state-of-the-art study (2) also provides a summary of possible measures that can be employed in responding to hazardous material spills. The countermeasures are divided into two major classifications: defensive and offensive. The defensive measures, which do not counteract the contaminant in the environment, consist of notifying all downstream water users of the occurrence of a spill and physically removing all bags, barrels and other containers which may still be leaking into the watercourse. The offensive measures include:

a The addition of acidic or basic solutions to neutralize the spill.

b The addition of specific complexing, chelating or precipitating agents for the formation of solids or compounds less toxic than the originally spilled contaminant.

c The utilization of large scale equipment to treat contaminated water in place with powdered activated carbon, a coagulant such as alum and a polyelectrolyte so that the resulting chemical floc precipitates the carbon together with the adsorbed contaminants.

d The physical removal of flocs, solids and liquids which have sunk to the bottom.

e The use of booming and skimming equipment to remove and contain light solids or liquids floating on the surface.

f Aid natural dilution to reduce concentrations of spilled materials to a level below critical concentrations by means of mechanical mixers, such as outboard motors, to augment flow of the materials.

g Contain spilled soluble materials so as to prevent diffusion throughout the aquatic environment, since most countermeasures are more effective with concentrated pollutants.

h Burning of floating volatile materials where air pollution and safety considerations permit.

4 Critique of countermeasures

In the critique of these countermeasures, the referenced study (2) points out the possible dangers that might result in applying several of these in that the resulting chemical compounds or precipitates may be more harmful to the environment than the original hazard. Disadvantages of existing carbon treatment methods are that granular carbon treatment can be employed only where some type of treatment facility already exists, and in the case of powdered carbon, the method is listed as speculative. Caution is advised in the use of the carbon techniques since there is reason to believe that the tremendous increase in the solids load may have undesirable effects. Removal of products which sink to the bottom by suction devices is listed as speculative since this method might involve the removal of large quantities of benthos along with the contaminant. Booming and skimming techniques, which have been widely used in the case of oil spills, provide a possible solution for spills of light insoluble materials. Mixing techniques for promoting dilution would be of value in only a limited number of circumstances. Containment techniques for soluble materials are not readily available. Burning techniques could be applied only in a very limited number of cases where the material remains confined in a small isolated area so as to minimize threats to safety and air quality.

5 Current status

It is clear from the above that adequate control, neutralization and treatment techniques for countering spills of hazardous materials are practically nonexistent. These countermeasures for the most part require technology not presently available. Nevertheless, it is considered that new and useful techniques can be developed by intensive experimental programs on spill control and cleanup methods.

Inasmuch as the Water Quality Improvement Act of 1970 (PL 91224) requires the designation of appropriate methods and means of removal of spilled hazardous materials, EPA's Division of Applied Science and Technology (Water Quality Office) has initiated Request for Proposal WA 71-513 on the development of methods to treat and control spills of selected high priority hazardous materials. The methods to be developed are to satisfy the following basic criteria:

a Result in no reactivity problems causing secondary damage to the environment including generation of harmful sludges.

b Easily obtainable and transportable equipment and chemicals.

c Minimum amount of auxiliary equipment.

d Light in weight.

e Reasonable first costs.

f Rapid application in both congested and remote areas.

g Safe to handle by untrained personnel.

Responsive proposals to the RFP are currently being evaluated and several contracts are expected to be awarded by June 1971. These contracts will cover a wide range of countermeasures for: containing spills before they reach surface waters; for containing contaminated water after a spill; and for decontaminating polluted water areas to return the water to a restored condition of quality. Specifically, some of the proposed countermeasures under consideration include:

a Development of devices to contain spilled hazardous materials on land by use of rapidly formed in place plastic dams or foamed dikes.

b Development of foamed plastic devices for stopping leaks of hazardous materials from ruptured containers both on land and underwater.

c Development of methods to polymerize and remove spilled hazardous materials on land and to prevent percolation of the materials into the ground.

d Development of rapidly deployable physical barriers which extend from above the surface of the water to the bottom of the waterway for the purpose of containing spilled hazardous materials in watercourses.

e Development of decontamination system using floatable mass transfer media (e.g. ion exchange resins and carbon sorption media modified to result in specific gravities less than 1) for: subsurface introduction into waterways; treatment of contaminants; and collection of spent media at the water's surface.

f Development of a continuous flow through thin film aerator to which chemicals can be added to neutralize, oxidize, precipitate or adsorb spilled hazardous materials from watercourses, and to develop a static sealed centrifuge to remove gases, precipitates, carbon slurries, and other solids from the effluent of the aerator device.

g Development of a modular transportable treatment system incorporating various unit processes such as neutralization, flocculation, precipitation, filtration and carbon adsorption, for the purpose of onsite removal and treatment of spilled hazardous materials in waterways.

REFERENCES

1 Spill Prevention Techniques for Hazardous Polluting Substances. Arthur D. Little, Inc. Report No. OHM 7102001, prepared under Contract 14-12-927 for the Environmental Protection Agency. February 1971.

2 Control of Spillage of Hazardous Polluting Substances. Battelle Memorial Institute, Pacific Northwest Laboratories, Report No. 15090 FOZ, prepared under Control 14-12-866 for the Environmental Protection Agency. November 1970

3 Public Law 91-224, 91st Congress, H.R. 4148. Water Quality Improvement Act. April 3, 1970.

This outline was prepared by I. Wilder, Chief, Hazardous Materials Research Section, Edison Water Quality Laboratory, OWP, EPA, Edison, NJ 08817.

PERSONAL SAFETY DURING HAZARDOUS MATERIAL SPILL OPERATIONS

I INTRODUCTION

Of major concern in the control of hazardous material spills is the protection of emergency response personnel from dangers of the spilled chemicals which are often extremely toxic and corrosive. The purpose of this outline is to provide general information on types of protective devices necessary to insure the safety of individuals during spill clean-up operations. Because of the multiplicity of chemicals that personnel may be exposed to during spill situations, details of specific safety equipment for specific hazardous substances are not possible at this time. Information contained herein are therefore only directed towards the reduction of the hazard potential of dangerous materials in general.

II TYPES OF EXPOSURE

The accidental release of chemicals to the environment may be inherently hazardous in different degrees. Improper protection can lead to severe personal injury. Injuries resulting from hazardous material spills are caused chiefly by chemicals or their fumes coming in contact with the body (skin and eyes) or through inhalation.

A Contact with Skin and Eyes

Contact of hazardous materials with the skin is of primary importance because it is the most probable type of exposure during spills. Many materials in direct contact with the skin will dissolve the fats and oils in the skin tissue. The most common result of excessive contact on the skin is localized itching, dryness, irritation or burn. But an appreciable number of materials are absorbed through the skin with sufficient rapidity to produce systemic poisoning. These materials may enter the body through the skin either as a result of direct accidental contamination or indirectly when the material has been spilled on the clothing. Some quite potent chemicals such as dimethyl sulfate can cause burns of disabling extent if but a few drops touch the clothing.

Contact of chemicals with the eyes is of particular concern because these organs are extremely sensitive. Very few substances are innocuous in contact with the eyes; most are painful and irritating and a considerable number are capable of causing burns and loss of vision.

B Inhalation

When hazardous vapors or gases are inhaled, they may pass into the general circulation system and may be distributed to the heart and central nervous system with extreme rapidity. Some vapors or gases act so violently in the upper respiratory system and lungs that they may cause unconsciousness or even death if the individual is not promptly removed to an uncontaminated atmosphere and given proper medical attention. Other vapors or gases may first cause mild symptoms such as headache, dizziness and fatigue, then nausea, intestinal, visual or mental disturbances and finally injuries to the blood, liver, kidneys or other organs.

III PROTECTIVE DEVICES

Personnel who may be called upon to work in atmospheres contaminated with hazardous substances should have special safety equipment and protective clothing readily available for emergency use. As a matter of good operational policy, it is important that all prospective users of these devices know where they are stored, how they are used and what are their limitations. It is also essential that all personal protective equipment be inspected and cleaned at regular intervals and always before use by another person. A general description of some of the basic personal protective devices are given below.

A Respiratory Protection

Self contained air or oxygen respirators are much safer than the air-purifying type, since the wearer carries either a supply of air or an oxygen generating canister, and this type does not depend on purification of the contaminated air for breathing purposes. In emergency situations, where the concentration of contaminants may be high or is unknown, only self contained respirators should be used. The supplied air or oxygen (hose type) respirator will not usually be applicable to hazardous material spill situations, since compressors or other air supplying devices may not be readily available and accessible during these emergency conditions. Also, the hose type respirators limit the wearer's freedom of movement, whereas the self contained units allow complete freedom. The pressure demand compressed air or oxygen respirator is considered the most fool-proof device since it provides positive breathing safety in the most dangerous atmospheres. Where longer exposure time is required, the self-generating oxygen respirator is a good alternative.

The U. S. Bureau of Mines has a testing section where respiratory devices are inspected and tested. The Bureau tests commercial respiratory protective devices and issues approvals to those which meet its standards. Maximum safety demands that only U.S. Bureau of Mines approved respiratory equipment be used.

Personal respiratory protection should be used as a primary protective device when it is necessary to enter a highly contaminated area for short periods of time. Respiratory protective equipment is basically of two general types:

1 Self contained or supplied air or oxygen respirators

2 Air-purifying respirators

There are several classifications within these two types:

1 Self Contained or Supplied Air or Oxygen Respirators

a Self Contained

These respirators provide the wearer with respirable air from a source of supply independent of the atmosphere where the wearer is located. They are entirely self contained and can be used in any atmosphere. The principal types of self contained respirators are:

1) Demand Compressed Air or Oxygen

In this device, compressed air or oxygen, contained in a cylinder worn by the user, is supplied through pressure reducing valves to a close fitting full face, rubber face piece only when the wearer inhales. There is no recirculation and the exhaled breath is directed to the atmosphere. These units are usually rated for 30 minutes duration and are equipped with alarm systems which warn the user when to leave the hazardous atmosphere because of diminishing air supply.

2) Pressure Demand Compressed Air or Oxygen

This respirator is a modification of the Demand Compressed Air or Oxygen Respirator. It is designed to provide an extra margin of safety for personnel who must enter atmospheres immediately hostile to life. This unit also provides air or oxygen on demand, but in addition, it maintains within the face piece a slight positive pressure above that of the outside atmosphere. This positive pressure prevents inward leaks of dangerous gases, thus assuring breathing safety in the most toxic environments.

3) Self-Generating Oxygen (Recirculating)

In this respirator, the exhaled breath is directed to a chemical canister which simultaneously releases oxygen by the action of the moisture in the breath on the chemicals and absorbs carbon dioxide from the breath. The breath containing the released oxygen enters a breathing bag (which is connected by tubing to the face piece) for inhalation, and the exhaled breath repeats the cycle. The canister for this respirator, under ordinary usage, can supply sufficient oxygen for one hour. Although this respirator is lighter than the pressure demand type, it is quite bulky, and once the seal on the canister is broken, the respirator must be used or the canister discarded.

b Supplied

These respirators supply air to the wearer through a hose from an uncontaminated remote source and are therefore independent of the atmosphere surrounding the wearer. Extreme care, however, must be exercised with these respirators in obtaining a safe air supply. It is important that blowers or other air sources be in an area which is free from air contaminants. These respirators provide relatively unlimited time of use.

2 Air-Purifying Respirators

This type of respirator offers limited protection, since it depends solely on gas-absorbing material or mechanical filtration media to remove specific contaminants from the air. Since this device utilizes the air surrounding the wearer, it is not suitable in an oxygen deficient atmosphere and must not be used in environments containing contaminants in concentrations higher than those for which it was designed. For example, air-purifying respirators do not offer protection when oxygen levels fall below 16% by volume or when concentrations of a toxic gas or vapor in the breathing atmosphere are greater than 2% by volume (20,000 parts per million). Similar to the self-contained respirators, these units have limited duration periods (about one hour). The following are typical air-purifying respirators:

a Chemical Respirators

In this device, inspired air is drawn over suitable chemicals in a cartridge where gaseous contaminants are removed. This respirator is usually designed for a particular contaminant only, but may also be designed for combinations of contaminants.

b Mechanical Filters

These are similar to the chemical respirators except that the purifying chemicals in the cartridge are replaced by filters. Filter respirators are designed to remove either a specific single particulate contaminant or several different contaminants.

c Combination Respirators

These are combined respirators, in one unit, for simultaneous protection against gases, vapors and particulates. They consist of chemical cartridges with mechanical filters in series, so that inspired air passes first through the filter and then over the chemical.

B Eye Protection

Eye protection is of major importance during spill emergency situations because of the ever present danger of injurious vapors or chemical splash. Personnel exposed to these situations should always wear suitable safety eye wear. There are numerous styles and types of safety glasses available. The following lists some of the representative types:

1 Plastic-rimmed safety spectacles with hardened glass or plastic lenses, available with or without side shields.

2 Plastic chemical splash goggles which fit the contours of the face and fit comfortably over all personal and safety spectacles. Some types of goggles also protect the nose and forehead.

3 Plastic face shields, which cover the entire face, can also be worn over personal and safety spectacles.

C Body Protection

Various specially treated protective garments including coats, suits, overalls, aprons, rain wear and similar clothing should be made available to personnel to safeguard the body against exposure to hazardous materials during spill emergencies. These garments should be made of solvent-proof plastics, synthetic rubbers or other suitable protective material resistant to corrosive chemicals.

D Foot Protection

Rubber safety boots with metal reinforced toe guards are recommended for protection from heavy objects and other foot hazards. Boots should be equipped with anti-skid outsoles to permit the wearer to have a reasonably secure footing even on oil covered surfaces.

E Hand and Head Protection

Many minor injuries to personnel may be prevented by the proper utilization of effective hand protection. Heavy butyl rubber or neoprene molded gloves should be made available to individuals involved in spill operations. These gloves are furnished in different sizes up to elbow length and are suitable for handling a wide variety of acids and other corrosives.

Personnel should also be provided with light weight plastic safety helmets (hard hats) to guard against head injuries.

F Miscellaneous Protection

Emergency response personnel should also be equipped with: battery-type lanterns for providing emergency illumination; an explosimeter to determine the explosive characteristics of an atmosphere; a portable oxygen indicator to quickly determine the oxygen content of a contaminated area; and portable first aid appliances.

IV FIRST AID

It must be recognized that, despite the most comprehensive precautionary practices during spill emergency operations, accidents will occur and, consequently, injuries to personnel must be anticipated. For this purpose, the following general first aid measures are suggested. For more detailed instructions, a recognized source, such as the "Textbook on First Aid" of the American Red Cross, should be consulted.

A Toxic Vapor Inhalation

1 Remove exposed victim to fresh air at once. (Rescuers should be properly protected).

2 If breathing has stopped, give artificial respiration.

3 Keep victim quiet, warm, lying down and obtain medical assistance.

B Skin Exposure

1 Immediately remove all contaminated clothing from victim. (Those assisting victim should wear suitable protective gloves).

2 Thoroughly flush skin with clean water to remove all traces of hazardous chemical.

3 Keep victim quiet, warm, lying down and obtain medical assistance.

C Eye Exposure

1 Continuously wash eyes with clean water for at least 15 minutes.

2 Obtain medical assistance, preferably an ophthalmologist with experience in handling chemical burns of the eye.

V SUMMARY OF GENERAL SAFETY PRECAUTIONS

Extreme care should be exercised by personnel involved in hazardous material spills. The hazardous chemical should not be allowed to come in contact with the unprotected skin or eyes, and inhalation of vapors should be avoided. If necessary to enter a spill area, PUT ON COMPLETE PROTECTIVE CLOTHING including goggles, boots, helmet, coveralls, gloves, etc. and WEAR SELF CONTAINED BREATHING APPARATUS.

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OIL POLLUTION - MAGNITUDE OF THE PROBLEM

I SOURCES AND AMOUNTS

A Broad Picture

Petroleum in its many forms has been on the move in the United States since 1859 when the first commercially successful oil well was developed in Pennsylvania. First transported by wagon and log raft, oil is now en route from the oil field to refinery to consumer by pipe, water, rail and highway. During 1970 more than 4.5 billion barrels of petroleum moved as crude oil from the production field through the refineries and then as refined products to the consumer. Ocean tankers, barges, pipelines, railroad tank cars and tank and trucks are the vital elements of the complex and diversified transportation system required to move this volume of oil.

Estimated amounts of oil lost (1) as well as the sources of this form of pollution are shown in Table 1. It is interesting to note that the loss of waste or used oil from vehicles (crankcase oil) may be the largest single source of oil pollution, larger, in fact, than the total volume from all sources lost directly to the oceans.

B Spill Frequency

Obtaining of one barrel of petroleum from the oil field to the consumer may require 10 to 15 transfers between as many as six different transport modes. Each mode is subject to accidents, and at the transfer points spill frequency is extremely high. Approximately one barrel of product is lost for each one million transported. About 7,500 oil spills are now occurring annually with an estimated total loss of 500,000 barrels (2). Most of the spilled oil is discharged to water. In addition to spills, the potential for discharges from normal vessel operation is in excess of 700,000 barrels of oil annually.

The number of spills and quantities lost vary with the type of transport system. About 217,000 miles of petroleum pipelines crisscross the United States transporting 45 percent of the Nation's annual consumption of petroleum. Pipeline failures accounted for only three percent of the product lost in 1969.

A United States fleet of 387 tankers and 2,900 barges presently operates in the Nation's waterways. In worldwide oil traffic, United States vessels make up only five percent of tanker traffic United States and foreign flag tankers were responsible for approximately 80-90 percent of the oil spilled in 1969.

Tank trucks and railroad tank cars together account for less than one percent of total product lost (2). Tank trucks are the last leg of the transportation system, delivering refined products to the retail consumer. Approximately 158,000 tank trucks are on the road. In areas not served by pipelines or navigable waterways, over 81,000 railroad tank cars take over the transport of crude and refined petroleum products.

C Why Spills Occur

Blumer (4) reported that human error accounted for 88 percent of the total number of spill incidents. The means of rectifying this situation is by better training and education, improved engineering, and when all else fails enforcement by a responsible State or Federal agency.

TABLE 1

ESTIMATES OF OIL INTRODUCED INTO WORLD'S WATERS AND POTENTIAL LOSSES TO WATERS, 1969

	Metric Tons Per Year		% of Total
1. Tankers (normal operations)			
Using Control Measures (80%)	30,000		
Not Using Control Measures (20%)	500,000		
	530,000		10.7
2. Other Ships (bilges, etc.)	500,000		10.1
3. Offshore Production (normal operations)	100,000		2.0
4. Accidental Spills			
ships	100,000		2.0
nonships	100,000		2.0
5. Refineries and petrochemical	300,000		6.0
SUBTOTAL		1,630,000	
6. Potential losses to water from industrial and automotive (not fuel):			
Highway vehicle spent oils	1,800,000		36.6
Industrial plus all other vehicles	1,500,000		30.6
SUBTOTAL		3,300,000	
TOTAL		4,930,000	

NOTE: Oil from pleasure craft and natural seeps not included.

Another important factor in the cause of spills by vessels is the stopping ability of the tankers under crash stop conditions--vessel in full reverse. It has been reported that(5, 3) the most important factor in connection with collision and stranding--the two most dreaded casualties--is the 'crash stop' ability. Unfortunately, the ability of tankers to come to a 'crash stop' has decreased as their size has increased. For the 400,000 tonner, the straight-line stopping distance for a 'crash stop' would be four to five miles and would take approximately 30 minutes. During this period of backing full, the ship's master is unable to steer her or regulate the speed. If the engines are not put 'full astern' but on 'stop' it takes up to one hour for the "Universe Ireland" to come to a stop.

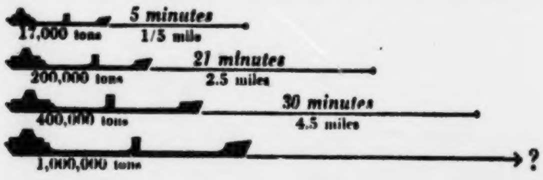

FIGURE 1

II ANALYSIS OF PAST MAJOR SPILLS

Dillingham Corporation(5) under contract to API, conducted a statistical study to develop an understanding of the basic characteristics of major oil spills--defined as a spill of 2,000 barrels (84,000 gallons) or more of a heavy (or persistent) oil which will not naturally evaporate or disperse rapidly in the environment--and thus define the nature and scope of the problem.

Based on an analysis of 38 past spills, which occurred during the period 1956 to 1969, they reported that:

A Source

75% were associated with vessels, principally tankers.

B Composition

90% involved crude or residual oils.

C Volume

70% of the spills were greater than 5,000 barrels with a median spill volume of 25,000 barrels.

D Distance Offshore

80% occurred within 10 miles of shore and the oil would reach shore within one day.

E Duration

75% of the spill incidents lasted more than five days with a median duration of 17 days.

F Extent

80% contaminated less than 20 miles of coastline with a median extent of four miles of coast.

G Coastline

85% occurred off shoreline considered to be recreational.

H Distance from Port

75% occurred within 25 miles of the nearest port.

Item (D) above is probably one of the most significant factors revealed by this study. As shown in Figure 2, fifty percent of the offshore spills occurred less than one mile from shore. Since oil appears to drift at approximately 3% of the wind velocity, and with an assumed average wind of 15 knots, the oil slick would drift at approximately 0.5 knots. Thus, with 50% of the spills less than one mile offshore, an onshore wind could move oil onto shore in two hours. The question that now arises is "how does one mobilize shoreline protection equipment during this short length of time?"

III MAJOR SPILL INCIDENTS 1956-1970

For reference purposes, major spill incidents along with significant characteristics, are shown in Table 2(3, 5).

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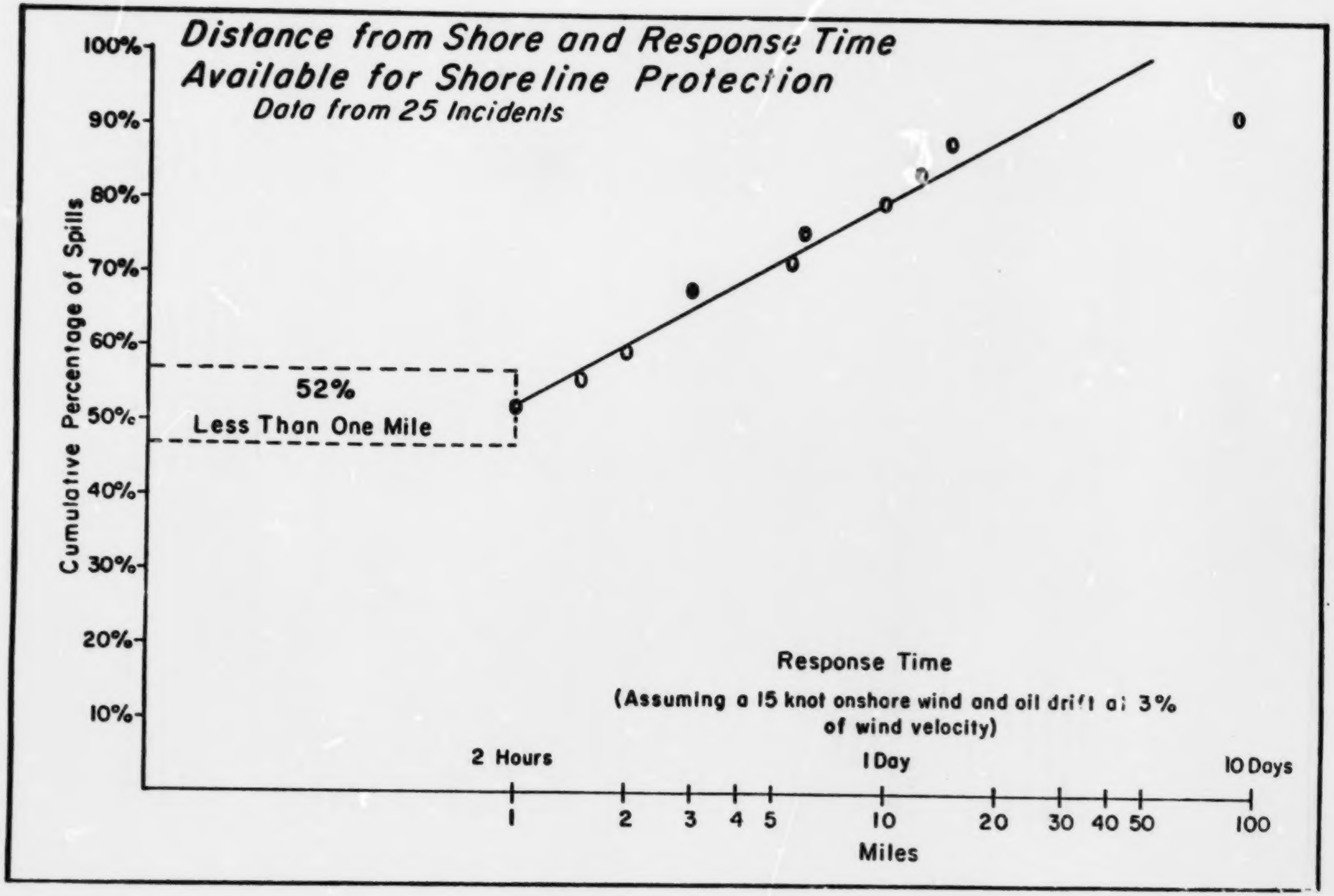


Distance from Shore and Response Time Available for Shoreline Protection

Data from 25 Incidents

TABLE 2

MAJOR OIL SPILL INCIDENTS

Name	Date	Cause of spill	Material	Volume (barrels)
ALGOL, tanker	02-09-69	Grounding	#6 F. O.	4,000
ANDRON, tanker	05-05-68	Sinking	Crude	117,000
ANNE MILDRED BROVIG, tanker	02-20-66	Collision	Crude	125,000
ARGEA PRIMA, tanker	07-17-62	Grounding	Crude	28,000
ARROW, tanker	02-04-70	Grounding	Residual	36,000
BENEDICTE, tanker	05-31-69	Collision	Crude	14,000
Bridgeport, Conn., terminal	6-15-70	Pumping	#2 F. O.	20,000
Chester Creek, pipeline	08-08-69	Break	#2 F. O.	3,500
CHRYSSI P. GOULANDRIS, tanker	01-13-67	Unknown	Crude	2,600
Dutch Coast Spill	02-16-69	Unknown	Residual	1,000
ESSO ESSEN, tanker	04-29-68	Grounding	Crude	30,000
ESSO HAMBURG, tanker	01-29-70			10,000
FLORIDA, barge	09-16-69	Grounding	#2 F. O.	4,000
GENERAL COLOCOTRONIS, tanker	03-07-68	Grounding	Crude	30,000
HAMILTON TRADER, tanker	04-30-69	Collision	Residual	5,000
HESS HUSTLER, tank barge	11-12-68	Grounding	#6 F. O.	40
Humboldt Bay, refinery	12- -68	Hose failure	Diesel	1,400
KENAI PENINSULA, tanker	11-05-68	Collision	Crude	1,000
KEO, tanker	11-05-69	Hull failure	#4 F. O.	210,000
Louisiana, Chevron platform	04-10-70	Fire	Crude	60,000
Louisiana, Shell platform	12-1-70	Fire	Crude	Unknown as of this date
MARTITA, tanker	09-20-62	Collision	Bunker C	4,300
Moron, refinery	03-29-68	Pumping	Crude	16,000
New Castle, power station	1963-65	Leak	Residual	40
OCEAN EAGLE, tanker	03-03-68	Grounding	Crude	83,400
R. C. STONER, tanker	09-06-67	Grounding	Mixed	143,300
Refinery Loading Site	1962	Hose failure	Crude	2,000
ROBERT L. POLLING, tank barge	05-10-69	Collision	#2 F. O.	4,700
Santa Barbara, platform	01-28-69	Natural faults	Crude	100,000
Schuylkill River, Berks Assoc.	11-13-70	Lagoon failure	Waste Crankcase	70,000
Sewaren, N. J., storage tank	10-31-69	Tank failure	Crude	200,000
Ship Shoal, drill rig	03-16-69	Storm shifting	Crude	2,400
Staten Island, N.Y., 2 Esso barges	05-22-70	Collision	#6 F. O.	10,000
USS SHANGRI-LA (CVA-38)	1965	Pumping	NSFO	200
TAMPICO, tanker	03- -57	Grounding	Diesel	60,000
TIM, tank barge	02-18-68	Sinking	#6 F. O.	7,000
TORREY CANYON, tanker	03-18-67	Grounding	Crude	700,000
Waikiki Beach	04-21-68	Unknown	Bunker C	
Waterford Beach	01-18-69	Unknown	#6 F. O.	
WITWATER, tanker	12-13-68	Hull failure	Mixed	15,000
WORLD GLORY, tanker	06-13-68	Hull failure	Crude	322,000

OIL REFINERY AND TERMINAL OPERATION

I INTRODUCTION

A petroleum refinery is an organized and coordinated arrangement of manufacturing processes designed to provide both physical and chemical change of crude petroleum into salable products with the qualities required.

II TYPES OF REFINERIES

Refineries can be classified as simple, complex, or fully integrated.

A A simple refinery will include crude oil distillation, catalytic reforming and treating. Its products will be limited to LP gas, motor fuels, kerosene, gas oil, diesel fuel and fuel oil.

B A more complex refinery will make a greater variety of products and require the following additional processes: vacuum distillation, catalytic cracking, polymerization, alkylation and asphalt oxidation.

C The fully integrated refinery makes a full range of products. Additional products will include lubricating oils, greases, and waxes. Additional equipment will include solvent extraction, dewaxing and treating.

A typical refinery flow plan for a fully integrated refinery is presented as Figure 1.

III TYPES OF CRUDE OILS

There are over 8,000 different types of crude oils in the USA alone and these vary from high to low sulfur content and from asphaltic to paraffinic and from heavy to light in specific gravity.

A The asphalt base crudes contain very little paraffin wax and a residue primarily asphaltic. These crudes are particularly suitable for making high quality gasoline and asphalt.

B Paraffin base crudes contain little asphaltic material, are good sources of paraffin wax, quality motor oils, and high grade kerosene.

C Mixed base crudes contain both wax and asphalt. Virtually all products can be obtained.

IV TYPES OF PROCESSES

A Atmospheric Distillation

Today's crude distillation occurs in towers containing a series of horizontal trays where liquid condenses, collects and is withdrawn. Since distillation is the most frequently used unit operation in refining, a drawing of a typical distillation column is presented as Figure 2.

The lighter, more volatile portions of the crude are withdrawn at the upper part of the tower and the heavier parts down lower in the tower. It is in this manner that the crude oil is first broken into its parts. Improved separation between products can be accomplished by installing more fractionating trays.

B Vacuum Distillation

Normally, it is desired to cut deeper into the crude oil than would be possible under atmospheric pressure and reasonable temperatures. Therefore, vacuum distillation is performed on the residual from the atmospheric distillation. This process is essentially the same as atmospheric distillation except it is fractionation performed under a vacuum.

C Catalytic Cracking

The rising needs for producing more gasoline per volume of crude oil led to the development of catalytic cracking. Here, a gas oil, not valuable for any other use, is fed to the catalytic cracking unit where it is cracked in the presence of a catalyst to gasolines and heating oils.

D Alkylation

Further needs for high octane gasolines led to the development of another process called alkylation where several components of the refinery gas streams are combined over a catalyst to make a high octane component.

E Polymerization

Here, again, this process was developed to utilize several components from a normal refinery gas stream and combine them into high octane number gasoline fractions.

F Platforming

This major process development consisted of the use of a platinum based catalyst to upgrade the octane number of naphtha distilled from crude oil to very high levels for use in aviation and high quality motor fuels.

G Hydrotreating

This process utilizes the excess hydrogen produced in the platforming process to remove sulfur compounds in many refinery products, motor fuel, lube oil and fuel oil.

H Hydrocracking

The use of hydrogen was extended to the hydrocracking process which converts petroleum residues by catalytic hydrogenation to refined heavy fuel oils or to high quality catalytic charge stocks.

I Coking

In this process heavy low grade oils are converted into lighter products and coke which is sold or burned.

J Treating Process

Many contaminants are present in crude oils in varying concentrations and include organic compounds containing sulfur, nitrogen and oxygen, dissolved metals and inorganic salts. These contaminants are removed at some intermediate stage or just prior to sending the finished product to storage. Numerous treating chemicals are used and most fall into one or more of these classifications:

1 Acid

2 Alkali

3 Solvent

4 Oxidizing agent

5 Absorption agent

V EFFLUENT WATER IMPROVEMENT PROCESSES

A API Separator

This equipment removes surfaced oil by skimming and pumping the skimmed oil to rerunning.

B Equalization Basin

Secondary oil recovery is possible here because of the large holding time.

C Flocculator-Clarifier

Coagulants are used to break emulsions and oil is removed by skimming.

D Biological Treatment

The activated sludge uses dispersed air for mixing and oxygen supply. The water can also be treated in trickling filters which are packed with high rate plastic media.

E Holding Basins

These basins are utilized to permit checking the quality of the effluent. If not satisfactory, it can be recycled.

F Ozonator

Here the phenols are reduced by oxidation and the water is partially sterilized.

G Activated Carbon and Rapid Sand Filtration

Here additional reduction of phenols is accomplished by mixing the activated carbon with the waste streams and removing it in sand filters.

VI TERMINALLING

A Tankers

1 Tankers are loaded or unloaded through flexible hose connected to shore pipelines or by means of loading booms made of conventional pipe connected by swivel joints.

2 Tankers are divided into two groups:

  a Dirty or black oil ships which transport crude oils, fuel oils and diesel fuels.

b Clean or white oil ships which carry highly refined products.

B Barge

Another form of transport is the barge usually used on long wide navigable rivers. Barges usually carry products rather than crude oil.

C Procedure for Handling Receipts

1 A discussion between the vessel people and terminal people should be held as soon as the vessel is properly hooked up. Sequence of discharging lines to be used, volume of each product and permissible pressure must be clearly understood.

2 Communications

Appropriate signals and means for transmitting them must be established. Telephone or walkie-talkies or hand radios can be utilized.

The vessel deck officer must be notified whenever a change in receiving tankage is to made so he can prepare for a pressure surge.

3 Identification of Lines

All lines and manifolds should be clearly marked so that the pipelines carrying each product are identified.

4 Manning

It is prudent operation to maintain one man on the terminal side of the facilities at all times and one man on the ship at all times so that in the event of an emergency the proper steps can be taken by each immediately.

5 Vessel Check

Prior to starting the ship's pumps or notifying the dock crew to begin transfer operations, the senior deck officer must assure himself that the entire cargo system is lined up properly.

6 Terminal Check

The terminal superintendent or his representative should be certain that all valves controlling flow to and from tanks involved in the discharge or loading are in their proper setting and that valves not involved in the transfer or loading are closed.

7 Use of Log

The use of a log reading the amount that the tank has received and comparing this volume with the amount that the tanker has discharged every two hours will quickly inform the terminal personnel that all material is finding its way into proper tankage or not.

8 Topping Off and/or Switching Tanks

Terminal manpower should always be assigned when the level of oil in a tank reaches a high point in that tank.

9 Tankage Assignment

Before the cargo arrives, it is important that the terminal people in charge of the receipt check the volume of space available to receive each product and conclude whether adequate space is available. This information should be entered on the log as the stop-gauge for the transfer for each specific product.

This outline was prepared by R. R. Keppler, R&D Specialist, Office of Water Programs, Boston Regional Office, Boston, MA 02203

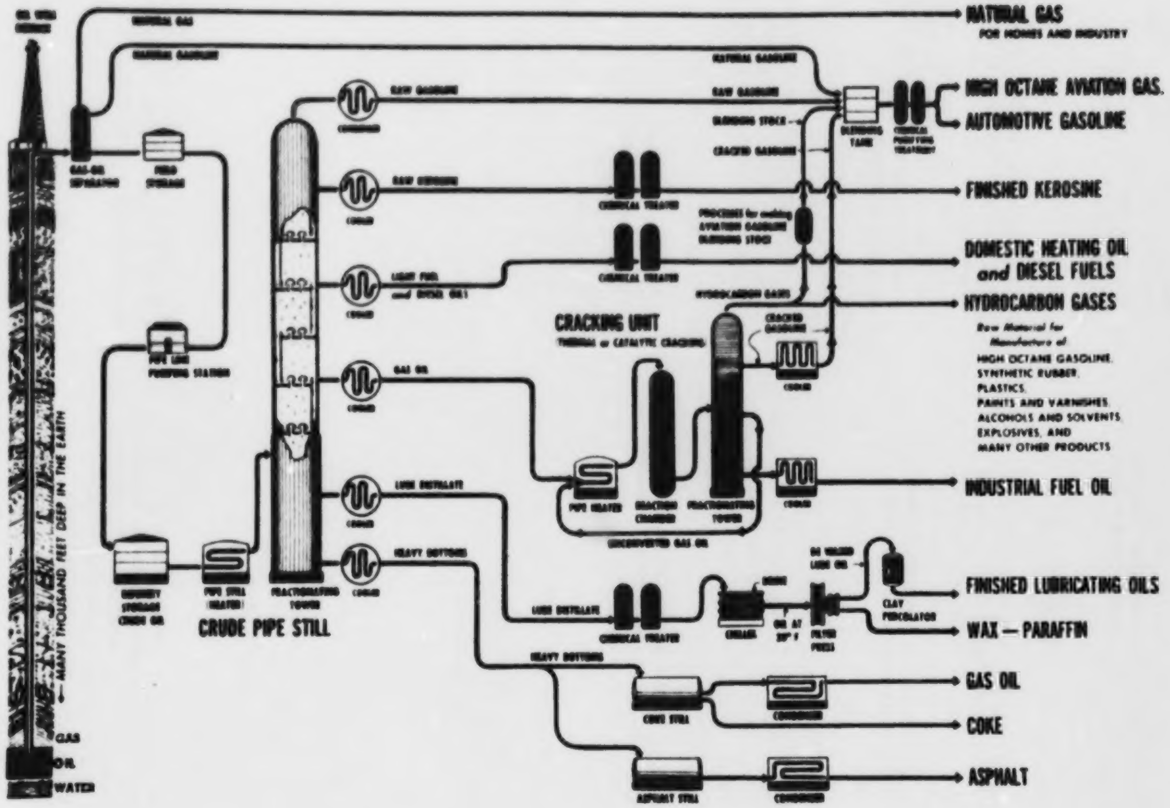

OIL WELL DERRICK
NATURAL GAS
NATURAL GASOLINE
GAS-OIL SEPARATOR
FIELD STORAGE
PIPE LINE PUMPING STATION
REFINERY STORAGE CRUDE OIL
PIPE STILL HEATER
FRACTIONATING TOWER
CRUDE PIPE STILL
RAW GASOLINE
CONDENSER
RAW KEROSINE
COOLER
LIGHT FUEL and DIESEL OIL
GAS OIL
LUBE DISTILLATE
HEAVY BOTTOMS
CHEMICAL TREATER
BLENDING STOCK
CRACKED GASOLINE
BLENDING TANK
HYDROCARBON GASES
CRACKING UNIT
THERMAL or CATALYTIC CRACKING
PIPE HEATER
REACTION CHAMBER
UNCONVERTED GAS OIL
CHILLER
FILTER PRESS
CLAY PERCOLATOR
COKE STILL
ASPHALT STILL
NATURAL GAS
FOR HOMES AND INDUSTRY
HIGH OCTANE AVIATION GAS.
AUTOMOTIVE GASOLINE
FINISHED KEROSINE
DOMESTIC HEATING OIL
and DIESEL FUELS
HYDROCARBON GASES
Raw Material for
Manufacture of
HIGH OCTANE GASOLINE,
SYNTHETIC RUBBER,
PLASTICS,
PAINTS AND VARNISHES,
ALCOHOLS AND SOLVENTS,
EXPLOSIVES, AND
MANY OTHER PRODUCTS
INDUSTRIAL FUEL OIL
FINISHED LUBRICATING OILS
WAX — PARAFFIN
GAS OIL
COKE
ASPHALT
MANY THOUSAND FEET DEEP IN THE EARTH
GAS
OIL
WATER

Fig. 1 Simplified Flow Diagram of Refinery

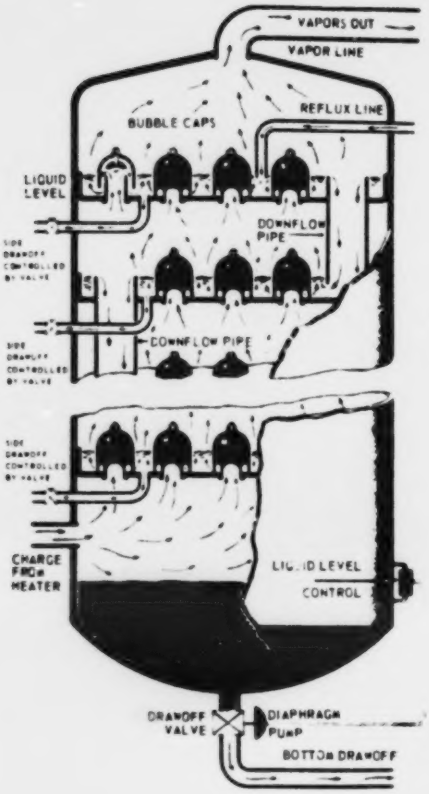

VAPORS OUT
VAPOR LINE
BUBBLE CAPS
REFLUX LINE
LIQUID LEVEL
DOWNFLOW PIPE
SIDE DRAWOFF CONTROLLED BY VALVE
SIDE DRAWOFF CONTROLLED BY VALVE
DOWNFLOW PIPE
SIDE DRAWOFF CONTROLLED BY VALVE
CHARGE FROM HEATER
LIQUID LEVEL
CONTROL
DRAWOFF VALVE
DIAPHRAGM PUMP
BOTTOM DRAWOFF

Fig. 2 - Bubble Cap-type Fractionating Tower

COMPLEX WASTES ASSOCIATED WITH PETROLEUM REFINERIES

I INTRODUCTION

Water is used in petroleum refining processes mainly as a cooling medium, to rinse impurities out of the oil, and to manufacture steam. In these uses the water is contaminated with a complex variety of materials. The nature and sources of these materials are discussed below.

II NATURE OF PETROLEUM

Crude oils are mixtures of many substances from which various oil products, such as petroleum gas, gasoline, kerosene, jet fuel, fuel oil, lubricating oil, wax, and asphalt are manufactured. These substances are mainly compounds of hydrogen and carbon, and are therefore called hydrocarbons. The various oil products may be described in a general way by their boiling range as shown in the following table (Table I).

Product	Carbon Atoms	Boiling Range °F
Fuel gases	1-2	-259 to - 128
Propane	3	-44
Butane	4	+31
Gasoline	4-12	100-400
Kerosene and jet fuel	10-18	350-570
Furnace and diesel fuel	11-22	355-700
Residue (asphalt)	20+	600+

III IMPURITIES IN PETROLEUM

Crude petroleum contains small amounts of impurities. Among these are:

Brine
Sediment
Sulfur
Nitrogen
Oxygen
Trace elements (copper, nickel, iron, vanadium, etc.)

As you will see later, some of these same impurities contribute significantly to the contamination of water used in the oil refining processes.

Crude oil, as it is brought up from underground, is mixed with briny water and sediment. Part of this is removed in the oil fields, but a small amount remains emulsified in the oil and must be removed at the refinery.

Petroleum is the product of decomposition of animal and vegetable matter, and contains elements present in the original living organisms. Among these are sulfur, nitrogen, and oxygen. Smaller amounts of such elements as copper, nickel, iron, vanadium, etc., are also present.

IV REFINERY FLOW DIAGRAM

No crude oil can provide a full range of finished products in the proportions and having the properties that the customers require. The function of a refinery is to make the required products - both directly from the crude or by converting the original material into saleable material. This is done by the following general steps: separation, alteration, purification, and blending.

A Distillation

The first step in refining is to separate, or distill, crude oil into parts or fractions. Each fraction has its own typical boiling range, as was seen in a foregoing table. Light fractions, such as gasoline and solvents, boil at low temperatures - while the heavier fractions, such as fuel oils, have higher boiling ranges.

Simple distillation can only produce those products which were in the original crude. In other words, a particular crude will yield only so much gasoline and so much jet fuel. So as the demand for gasoline increased, refineries brought into use a process called "cracking".

B Cracking

In cracking, the heavy, high-boiling parts of the crude oil are broken down by high temperature into lighter fractions boiling in the range of gasoline, jet fuel, and diesel fuel. In the earlier cracking processes - thermal cracking and coking - high temperature alone was used to accomplish cracking. Later catalysts were also used to improve the yield and quality of the gasoline produces. The latest cracking process - hydrocracking - uses not only high temperature and catalysts, but also high pressure and an atmosphere of hydrogen.

C Alkylation

Cracking the heavier parts of crude oil to produce lighter fractions is something like breaking larger rocks into smaller ones. In the fracturing process some small particles are formed. Joining these smaller molecules together to form material in the gasoline range is done by cracking-in-reverse processes called alkylation or polymerization.

D Catalytic Reforming

Gasoline fractions distilled directly from crude oil would cause "knock" in your modern high-compression automobile engine. In the catalytic reforming process the chemical structure of the gasoline is rearranged to improve its anti-knock rating.

E Treating

From the primary refining operations described in the sections above a wide range of product streams are obtained. In most cases the properties of these streams, either as final products or as feedstocks for futher processing (for example reforming) are adversely affected by certain impurities. These must be removed or converted to less harmful compounds by further refining processes called "treating". The undesirable constituents are mainly sulfur, nitrogen, and oxygen compounds from the original crude oil and unstable materials formed by cracking which would later form gummy residues.

The most modern of the treating processes is hydrodesulfurization. In this process the sulfur compounds are converted to hydrogen sulfide, the nitrogen compounds to ammonia, and the oxygen compounds to water. The hydrogen sulfide can be converted to saleable sulfur by partial combustion with air.

Older treating processes extract the undesirable compounds using a variety of caustic solutions or sulfuric acid. In most of these processes the solution is continuously regenerated and the undesirable extracts are incinerated or recovered for sale as by-products.

V REFINERY WASTE WATER SOURCES

In a typical refiner, the large-volume sources of waste water can be grouped in three categories, as follows:

Table II

Refinery Waste Water Sources

Source	Flow, GPM	% of Total	Source of Contamination
Cooling Water	100-6,000	40-80	Process leaks, treating Chemicals and Concentration
Water Softener & Boiler Blowdown	5-300	< 10	Treatment and concentration
Refinery Processes[1]	20-1,200	20	Direct contact with oil and treating chemicals

Although the largest percentage of the water discharged from a refinery was used for cooling, purposes, the actual amount varies widely from one refinery to another. This depends on whether the cooling system is once-through or recirculating and to some degree the extent of use of air coolers.

Cooling water is normally called non-oily. This is relative, however, since the cooling water can become oily through leaks in heat exchangers. These leaks and treatment chemicals used in the cooling systems are the main sources of contamination in cooling water.

Pollution in a waste stream from water softening and boiler blowdown is relatively minor. Although relatively small volumes of water are involved, the dissolved solids content may be high. Chemicals used to treat the boiler water are the main pollutants.

The greatest sources of pollutants in a refinery are the so-called process water or oily water streams. This contamination occurs when the water is used in direct contact with the hydrocarbon process streams. Often this water was used as steam to strip material from process streams, such as sulfides or mercaptans.

---

[1] Crude oil desalting, overhead oily waste from units such as distillation, cracking, alkylation, treating, etc.

The following table lists the pollutants and approximate concentrations which may be found in refinery waste water streams.

Table III

Undesirable Components of Refinery Waste Water

Pollutant	Concentration, ppm
Floating and dissolved oil	1-> 1,000
Suspended solids	--
Dissolved solids	0-5,000
Phenol and other dissolved organics	0-1,000
Cyanide	0-20
Chromate	0-60
Organic nitrogen	0-50
Phosphate	0-60
Sulfides and mercaptans	0-100
Caustics and acids	2-11 pH
Color and turbidity	--

Visible oil on the surface of waste water is the most common and troublesome pollutant in refinery waste water. Concentrations can range from 1 ppm to well over 1,000 during accidental spills.

Crude oil entering a refinery usually contains suspended solids and as much as 1% brine emulsified in the oil. These impurities are washed out of the crude using water in a device called a desalter. Water drained from the desalter will thus contain suspended dirt and as much as 5,000 ppm of dissolved salts. A relatively high content of dissolved solids can also be expected in the blowdown from cooling towers, boilers, and water softeners.

Phenol and cyanide are very important to water quality criteria. Only very low concentrations are tolerable in drinking water. Cyanides are not generally considered as a major problem to refineries because they are not often found at significant levels. Phenols, on the other hand, occur in some crudes and are formed during cracking, and are a very common pollution problem in the petroleum industry. Some process waters contain phenol concentrations as high as 1,000 ppm.

Chromium and phosphate compounds are commonly used as corrosion inhibitors in cooling water systems. Phosphates are also sometimes used to treat boiler water.

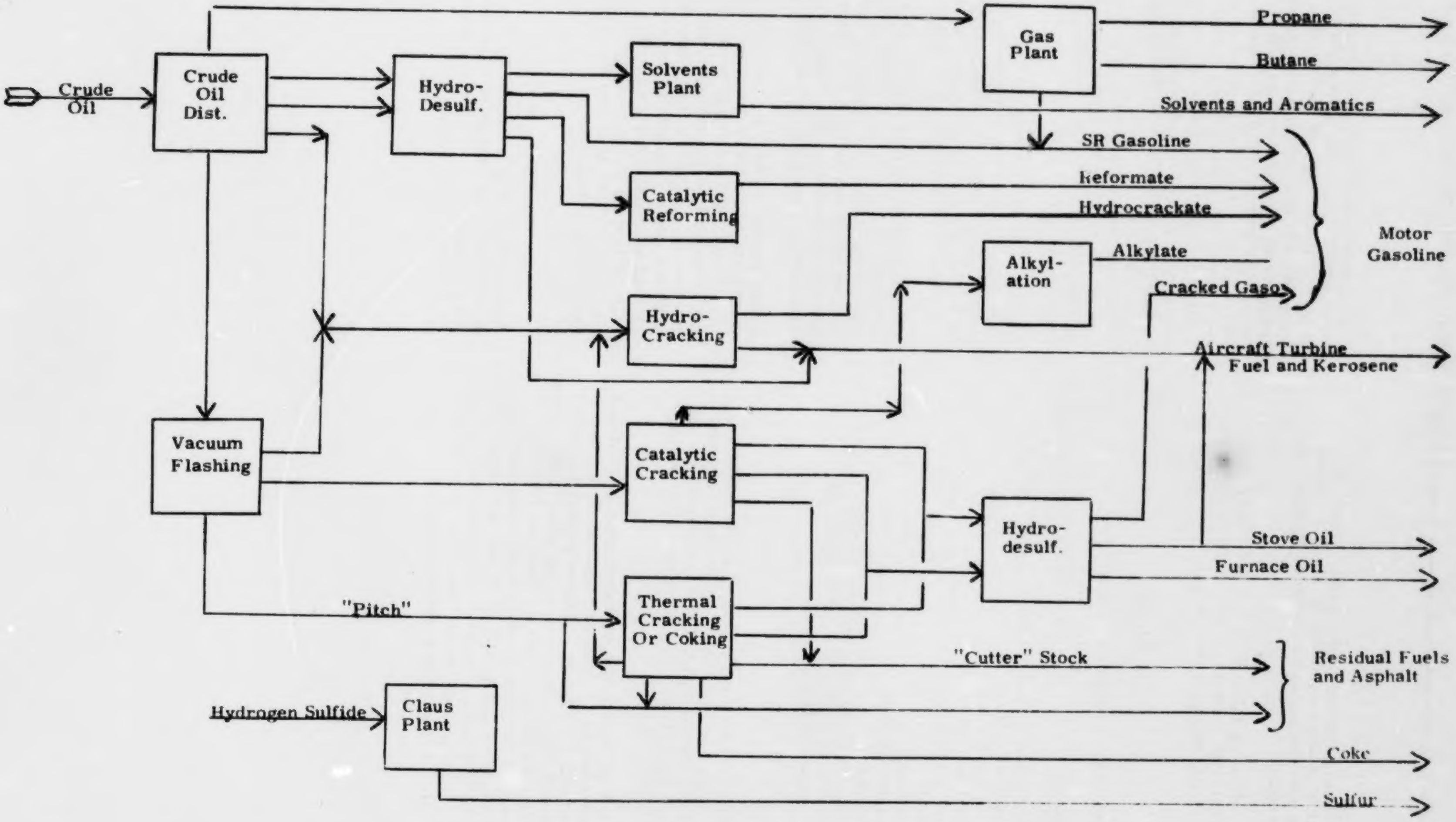
Ammonia and other nitrogen-containing compounds are commonly found in the process waters of cracking units and hydrogenation units, as the result of decomposition of nitrogen compounds in the original crude oil.

Mercaptans and sulfides are commonly present in waste water streams within a refinery. Special facilities and vigilance are required to keep them out of the final effluent. These materials of course are odiferous and can be detected in very small concentrations.

Caustics and acids are occasionally used for treatment of refinery streams, as previously mentioned. Where these spent treating chemicals are drained into the effluent water, the presence of phenols, organic acids, mercaptans, and sulfides can be expected. Inadvertent spills of acid or caustic can cause correspondingly high or low pH in the effluent water. Caustic or acid extracts also tend to cause a brownish coloration of the effluent.

This outline was prepared by R. E. Van Ingen, Coordinator of Design and Development of New Processes - Shell Oil Company, New York, NY 10020

MODERN REFINERY
SIMPLIFIED FLOW DIAGRAM


Crude Oil
Crude Oil Dist.
Hydro-Desulf.
Solvents Plant
Gas Plant
Propane
Butane
Solvents and Aromatics
SR Gasoline
Catalytic Reforming
Reformate
Hydrocrackate
Alkyl-ation
Alkylate
Cracked Gaso
Motor Gasoline
Hydro-Cracking
Aircraft Turbine Fuel and Kerosene
Vacuum Flashing
Catalytic Cracking
Hydro-desulf.
Stove Oil
Furnace Oil
"Pitch"
Thermal Cracking Or Coking
"Cutter" Stock
Residual Fuels and Asphalt
Hydrogen Sulfide
Claus Plant
Coke
Sulfur

WASTE TREATMENT METHODS FOR REFINERIES

I INTRODUCTION

A Requests for information to evaluate water requirements, wastewater treatments and possible surface or ground water pollution by oil refineries requires extensive study. It is always necessary first to have knowledge of size of refinery, type of crude oil, classification of refinery (topping plant, topping and cracking plant, topping, catalytic cracking, plus lubricating processing or a combination of all processes)[1] and the products to be produced. Each refinery is built to satisfy a certain market for its products. A corporate management often develops certain processes that are common only to that organization. Therefore, it is only possible to supply generalized information until definite plans, elevations and location relative to other industries and developments are available.

B For those who require an understanding of the problems of crude oil or petroleum processing, Bland and Davidson[2] is an excellent text. It furnishes both general and technical information relating to the processing of crude oil into useful products. This book has a limited section on sources of crude oil and preliminary "crude assays." It has extensive sections on processing, equipment, chemicals and catalysts, maintenance and construction. There is also a section on offsite facilities that includes tankage, blending areas, cooling systems, refinery sewer systems, waste treating facilities and utility plants.

C The 1968 Refining Process Handbook[3] describes many of the latest refining processes.

II WASTEWATER PROCESSING AND QUALITY CONTROL

A Beychok[4] reviews the subject of aqueous wastes. Following a chapter on "Pollutants and Effluent Quality Regulations," he describes in "Refinery and Petrochemical Plant Effluents," three means of segregating the waste streams of oil processing plants, then reviews the various process waste streams. In a chapter on "Treatment Methods" he details inplant treatment prior to the use of API separators with final "Secondary Treatment." He also has chapters on "Miscellaneous Effluents," "Cost Data," an "Appendix, including a Glossary, description of IOD, BOD and COD Tests," and an excellent reference list into the year 1966. This is the latest and most complete text on petroleum and petrochemical plant wastewater.

B Much has been done by the American Petroleum Institute, Refining Division, toward handling of waste streams.[5] A copy of the manual should be available to all involved in the study of refining waste streams.

The 1967 Domestic Refinery Effluent Profile[1] was developed to indicate just what the sources of waste are and what the various refineries are doing. This report divides the various types of refineries into:

1 Topping plants

2 Topping and cracking plants

3 Topping, cracking and petrochemical plants

4 Topping, catalytic cracking and lubricating oil processes

5 Plants, including all processes

The types of wastewater treatments are also described in general terms by code number.

C Another series of reprints on waste treatment is "Waste Treatment and Flare Stack Design Handbook."[6] This series of reprints covers the fundamentals of sewer design through wastewater treatment plans and the water laws that influence the petroleum industry.

D Chemical Engineering[7] presents a "Complete Guide to Pollution Control (Deskbook Issue)" which includes a number of articles for the control of pollution.

E The National Petroleum Refiners Association published reprints of papers presented at their various meetings. A series of these are attached.[8]

F Dr. A.J. Freedman[8a] points out that a normal refinery operation requires 18.3 barrels of water per barrel of crude processed. Since, as mentioned earlier, no two refineries are alike, information presented here cannot be expected to fit all waste treatment operations. Dr. Freedman's sources and classification of refinery wastewater are outlined in his Tables I and II of this paper.

G Stevens and Evans[8c] state on page 1, "Both the process design and operations groups have generally defined a waste stream as one from which economic gain cannot be achieved in the allowable payout period for capital amortization." On page 2 there is a complete list of parameters that should be closely observed. This same paper states "The techniques available to the designer of waste control flow sheets in the refinery are literally all those available to the designer of the process flow sheet and, in addition, have the powerful tool of biological treatment--a not very common concept in the lexicon of process flow sheet designers."

1 Many other ideas and suggestions for wastewater quality control can be found in the various NPRA reports.

2 Other references are from the Oil and Gas Journal.[9]

H Mr. Hickey[9a] has an excellent short article which includes a suggested wastewater survey, water use and possible contaminates along with pollution concentrations and determinations. Two articles by Ewing[9b, 9c] review the refinery's use of activated sludge and lagoons in wastewater treatment.

To become knowledgeable of the works of others, the staff of American Oil Company[10a] describes the treatment of oil wastes, and Quigley and Hoffman[10b] describe the flotation of oily wastes.

I While the title speaks only of the Petrochemical Industry, S.K. Mencher[11] reviews both the refining and petrochemical industry. This is an extensive report listing process units, source of pollutants, pollutants and possible terminal remedy. Mr. Mencher outlines a schematic diagram of terminal waste disposal facility for refinery petrochemical complex. This includes 1) oily water or process water, 2) sanitary sewers 3) demineralizer waste and 4) oil free waters. It is stated that "The bulk of water and in hydrocarbon processing industries, is used for cooling purposes and does not ordinarily become contaminated. However, during process operations, waste streams are released from equipment to the sewers at many points because of leaks, water purging and line breakage."

Mr. Mencher indicates that "polluted water streams are often disgorged in the following processing operations:

1 Crude oil desalting

2 Steam distillation

3 Steam stripping

4 Water washing of products following chemical treatment

5 Barometric condensing of steam driven prime movers

6 Catalyst regeneration

7 Partial pressure reduction with dilution steam

8 Boiler and cooling tower blowdowns

9 Drainage of contaminated areas--rain water runoff

10 Treatment of water--i.e., nitrate addition for caustic embrittlement control

11 Transferring and storing oils

12 Vessel cleaning operations"

The ultimate disposal of any waste stream leaving process units must be treated by either of three methods, or a combination:

1 Physical - separating, skimming, burial, i.e., gravity separators

2 Chemical - neutralization, oxidation, reduction, i.e., chemical flocculation, air flotation

3 Biological - bacterial oxidation, anaerobic processes, i.e., biological oxidation

III SOURCE WATER AND SHIPPING CONSIDERATIONS

A As in the case of any steel mill, paper mill, thermal electric power plant, or hydrocarbon processing facility that uses and releases large volumes of water, the source of water should be known and a study made of the direction of flow of any discharge. John Piety [12] describes such a study in Predicting the Course of an Effluent Discharge for the south coast of Long Island, New York. This survey traced the underwater effluent from a sewage treatment plant and included the effect of winds, tides, and coastal currents. Ross[13] is able to predict pollutant dispersion by the mathematics of diffusion. The equations are derived from "equation of change" describing mass transport or from macroscopic balances. His solutions yield relations desired for correlating dispersions.

B Any time petroleum--either crude or refined products--are shipped there are possible hazards. In the case of tankers and particularly those carrying 2.5 million barrels, the damage that could be done in case of an accident is untold. It is necessary, therefore, to maintain systems that prevent spillage and if there are, have safeguards such as extensive oil booms and enclosures to prevent release of oil to the water course. All dockage should be protected. All tankers necessarily have a certain amount of ballast water and tank cleaning emulsions to dispose of. API Manual on Disposal of Refinery Wastes, Volume 1, Wastewater Containing Oil,[2] Chapter 5, "Disposal of Ballast Water and Tank-cleaning Emulsion from Tankers and Barges," and Brummage, et al.,[14a, 14b] review some of the many problems and possible solutions. Where both the crude oil is shipped in as well as products trans-shipped by water, the hazards are great.

IV REQUIREMENTS

In any proposed refinery, it must be emphasized that certain information be available to the Environmental Protection Agency and/or other agencies having the safeguard of water as their responsibility. This includes the name of the company responsible for the refinery, the source of crude oil, the methods of receiving and possible trans-shipment of products, the docks and protective harbor, type of operation, whether a topping plant or a more complete refinery, the names of designing engineering firm, storage, kind and how much. These, plus water needs and wastewater disposal are requirements.

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This outline was prepared by L.W. Muir, former Chemist, National Field Investigations Center, EPA, Cincinnati, OH 45213.

PLATFORM OPERATIONS - OFFSHORE OIL PRODUCTION

I INTRODUCTION

A More than 100 companies are now active in offshore petroleum, operating off the coasts of 75 countries. The value of the work in progress is about $3 billion and at the end of 1970, the total investment in the offshore oil industry has amounted to about $20 billion.

Daily offshore U.S. production is in the range of 1.30 million barrels of oil, representing 14.5% of the domestic total. Proved reserves of offshore oil stand at 85 billion barrels, or about 20% of the estimated world inventory of 425 billion barrels.

In 1969 approximately 1,160 wells were drilled in the offshore U.S. areas. At the present time there are 2,564 offshore platforms, structures and facilities in the Gulf of Mexico, off the California coast and in the waters of Alaska. Of this number, 764 are in navigable (3 miles from shore) waters. Even though water is not discharged from all these platforms, structures and facilities, they do constitute a potential source of pollution due to blowouts and other accidents.

B Current practice in the offshore oil industry is to group platforms, structures and facilities, located in particular fields, for economy in operation. Thus, for example, one main platform may serve as the supporting facility for ten or more structures. This main platform then provides living quarters, office space, treatment facilities and control centers for the other structures in the group. At an average bare-bones cost of $8 million, real estate on these main platforms runs about $40 per square foot with an average surface area of 200,000 square feet. These surface areas and cost figures play an important role in the selection of water treatment equipment.

II TREATMENT OFFSHORE

A The original carboniferous deposits accumulating within, or at the edge of, ancient seas constituted the beginning of petroleum formations. It therefore follows that some part of those ancient seas will be produced with the oil and gas today. This water, which accumulates during the production processing of oil and gas, is frequently great in volume sometimes exceeding 20,000 barrels per day for one field. This water may constitute from less than 10% to greater than 50% of the total fluids produced from a single well.

Depending on several variables, an offshore operator may decide to:

1 Pump the entire oil/water mixture to shore for treatment.

2 Pump the oil/water mixture to shore for treatment following a free-water knockout process.

3 Treat the oil/water mixture on the platform and sell the oil to a pipeline company at the platform.

This last choice requires that the oil contain a maximum of 2% water and generally no more than 1% water.

The variables upon which the above decisions are based include:

1 Distance to shore - 20 to 30 miles is generally the maximum.

2 The presence and types of solids and emulsions concerned.

3 The relative specific gravity of the oil and water.

4 The chemical characteristics of the oil - the paraffin content plays an important role.

5 Economics of treating on shore vs. on the platform.

6 The percent of water produced with the oil.

Treatment equipment must take into account the fact that the above variables change with time. This requires that adequate safety factors be included in design calculations.

B There are two basic types of equipment associated with oil/water separation on offshore production facilities:

1 Operation equipment

2 Conditioning equipment

Operation Equipment - That equipment used in the process of separating well gas from fluids and processing fluids to remove WATER from the OIL. Depending upon the throughput volume in operation equipment, and also upon the presence and types of solids and emulsions concerned, the character of the various emulsifying agents and the relative specific gravity of oil and water, the oil contamination in the separated water will frequently be from 200 ppm to 3,000 ppm or more. As the water content in the product oil decreases, the oil content in the effluent water increases. Therefore, the 2% maximum (and 1% desired) water content required by the pipeline company has a direct bearing on the amount of oil that must be removed from the discharge, or bleed, water.

Process units that may be classified as Operation Equipment include the following:

1 Emulsion treaters

2 Heater treaters

3 Free-water knockouts

4 Phase separators (gas, water and oil)

Prices for this equipment range from $3,000 for a 12,600 gallon free-water knockout separator (4 hour detention time) to $52,000 for a heater treater handling 10,000 barrels per day.

The free-water knockout and phase separators are essentially sedimentation tanks wherein the gas, oil and water separate by gravity under pressure. Valves, located at the phase interfaces, draw off the particular components. The emulsion and heater treaters make use of emulsion breakers (either chemical or heat) to more effectively remove the water phase.

Conditioning Equipment - That equipment used downstream from the operational equipment to treat bleed water prior to disposal overboard. This equipment removes OIL from the WATER. Depending upon the same variables which effect the operation equipment, the effluent from the conditioning equipment will contain from 20 ppm to 200 ppm oil. Close observation is required in order to maintain an effluent in the 20 ppm to 50 ppm oil range. This is not always achieved.

Units which may be classified as conditioning equipment include:

1 Gravity separators

2 Oil skimmers

3 Clarifiers

4 Gas flotation cells

5 Coalescers

This conditioning equipment can be installed at a cost of $2 to $3 per barrel or $20,000 to $30,000 for a system designed to process 10,000 barrels per day. This cost is based on the assumption that the equipment would be customized and designed to achieve an effluent of 50 ppm oil. This system would occupy about 300-400 sq ft and would require 3-4 months for delivery. The price would double if the equipment were installed after construction of the platform was completed.

Chemical treatment may be used to provide more consistent results in the 50 ppm oil range. This, however, generates a large amount of sludge which is a disposal problem in itself. Operating data indicate 30 to 500 lb/day ferric chloride would be needed to obtain 50 ppm oil. This would generate 4 cubic feet of sludge for each pound of chemical used.

Gravity separators, oil skimmers and clarifiers rely on the gravity separation of oil from water. Oil is normally skimmed off the top of these units and water is drawn from the bottom by way of an outside siphon called a "Gun Barrel". These units are normally used upstream from other oil removal equipment to eliminate the bulk of free oil and sedimentation.

Gas flotation units saturate "clean" water with gas in a pressure tower. This water is then mixed with the water/oil mixture in a flotation chamber in which the gas bubbles expand and carry the oil particles to the surface where they are skimmed off. "Clean" water is then drawn off and discharged with a portion being recirculated to the gasification pressure tower. These units are capable of removing 90 percent of the oil from influents ranging as high as 1000 ppm oil.

In coalescer units the water/oil mixture enters a settling section where heavier solids fall out and free oil rises to the surface. The flow then travels through a graded filter bed or excelsior section where oil wetted particles are filtered out and finely dispersed oil particles are coalesced to particle size sufficient to rise out of the water. After filtering, the water passes to a final settling and surge section.

C New proprietary equipment is being developed by several companies which, it is hoped, will reduce the amount of oil in the bleed water, and at the same time reduce the equipment space requirements. To date, this equipment has not been in service offshore but based on existing data, it is felt that effluent concentrations of 10 ppm to 25 ppm oil are achievable. The space requirements for these units range from 50 to 80 square feet, with cost estimates from $20,000 to $30,000 installed offshore.

III SUMMARY

By 1980 exploratory drilling and possibly production will be extended to coastal shores and slopes of about 120 countries. The estimated value during that year will be about $14 billion and the cumulative value of offshore operations will be more than $50 billion.

The offshore oil industry is expanding at a rapid pace and as the industry grows so does its associated pollution problems. Present conditioning equipment is capable of producing effluent bleed water with oil concentrations in the 10 to 200 ppm range. If operated properly, this equipment can discharge effluents which do not produce oil films, sheens or discolorations in the receiving water. The equipment costs about $2 to $3 per barrel per day to install and requires 300-400 square feet of valuable platform space.

The more efficient equipment which is currently under development will produce bleed waters with oil concentrations in a consistent 10 to 25 ppm range. These new units are needed so that the offshore industry can continue to grow without placing additional loads on an already overburdened environment.

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CHEMICAL AND PHYSICAL CHARACTERISTICS OF OIL

I INTRODUCTION

The purpose of this discussion is to encourage curiosity about, as well as an understanding of the colored, somewhat viscous, odorous liquid that floats on water and is called oil. An over view of the many different chemicals that are found in oil is presented, as well as a description of how a modern analytical laboratory identifies individual oils, and determines the amount of oil emulsified in water.

II PROPERTIES OF OIL

Oils differ from each other in physical and chemical properties. These properties and the materials in oil that give rise to them, are examined in the laboratory.

A Physical Properties

1 Description

Oils can be described by physical properties such as, color, viscosity, odor, density or specific gravity, and flammability. Four common oils serve to illustrate these properties. Two of these, Bachaquero and South Louisiana, are crude oils in the same form in which they are extracted from the ground. The other, No. 2 and No. 6 fuel, are commercially modified oils. Bachaquero and No. 6 are almost black in color, South Louisiana is very dark brown, and No. 2 is light brown and fairly transparent. The viscosity of these materials, i.e., their "thickness" varies greatly: No. 6 is a thick paste that does not flow; Bachaquero is less viscous and does flow; South Louisiana has approximately the viscosity of light mineral oil and flows readily; while No. 2 is still less viscous and flows very readily. All four oils have a characteristic petroleum odor and all burn. When these materials are mixed with water, they separate as a top layer on water and are, therefore, described as less dense than water. Oils can, therefore, be distinguished in terms of their physical properties in the same way as by name or number. Such properties as color, viscosity, flammability, density, and odor, help to identify materials as to the type of oils and to distinguish one from another.

2 Laboratory Examination

When oils are brought into the laboratory, tests are performed that define their physical properties more precisely. Accurate measurements are made of the viscosity, i.e., how "thick" the oil is, as well as the density or specific gravity, i.e., how much of a tendency this material has to float on water; exact numbers are assigned to these parameters. These measurements are so accurate that oils whose thicknesses or viscosities are very similar and whose densities appear identical to the naked eye can be distinguished from one another. The flammability or tendency of an oil to burn is also very accurately measured in the laboratory. This test is performed by heating a portion of oil very slowly while passing a flame over its exposed surface. The temperature attained by the oil at the moment of ignition is called its "flashpoint".

A number of other physical properties of oils are also examined in the laboratory and used to distinguish one oil from another. These properties include pourpoint, which is the lowest temperature at which an oil will flow; cloud point, which is the temperature at which materials begin to crystalize out of the oil and thereby cause it to become cloudy; and ash content, which is the amount of non-combustible material in oil.

The various physical tests share one thing in common. They all examine oil as a single entity, or material. But actually, oils are mixtures of hundreds or thousands of individual materials. When oils are considered in this way, a discussion of chemical properties becomes important. Chemical properties, as well as the individual materials that constitute oils, are examined in the analytical laboratory.

B Chemical Properties

1 Description

Most materials that make up typical oils are members of a family group called Alkanes. These materials exist as chains of carbon atoms connected together and to hydrogen atoms (Fig. 1 - 2). Such aggregates of atoms are called molecules, and the forces that hold the atoms together are called bonds. Different combinations of atoms and bonds are possible, but two rules must be followed when molecules are represented schematically: only one bond, i.e., a single line can be drawn between any two atoms; and exactly four lines must be connected to every carbon, while only one line to each hydrogen. The simplest structure consists of one carbon connected to four hydrogens (Fig. 1), and is a molecule of the compound methane. Two carbons connected to six hydrogens (Fig. 2) represent a molecule of the compound ethane. Methane and ethane are the simplest members of the Alkane family. The molecular structure of other members of this family varies in complexity and in the number of carbon atoms that comprise the chains. Some molecules contain "branched" chains. A carbon to which a branch is attached can in turn be attached to only one hydrogen, or to no hydrogens (Figs. 3 - 4). Alkanes also exist as "cyclic" structures where carbons form closed loops, and each carbon is attached to two hydrogens (Fig. 5). Most Alkanes are molecules that incorporate several of these features (Fig. 6), and differ in the number of atoms in their molecules; some molecules are small, while others are very large. This variety in molecular structure and size gives rise to a tremendous number of different materials that belong to the Alkane family.

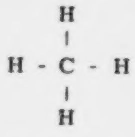

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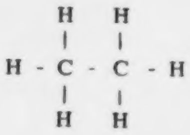
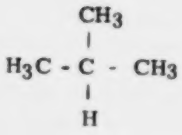
Fig. 1



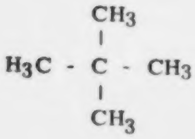
$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Fig. 2



$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ H_3C & - & C & - & CH_3 \\ & & | & & \\ & & H & & \end{array}$$

Fig. 3



$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ H_3C & - & C & - & CH_3 \\ & & | & & \\ & & CH_3 & & \end{array}$$

Fig. 4

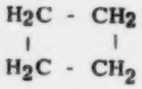


Fig. 5

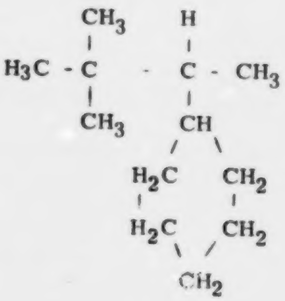


Fig. 6

2 Laboratory Examination

Oils are mixtures of hundreds or even thousands of different materials. Most of these materials, usually more than 90% belong to the Alkane family. Their number and relative proportion in different oils is staggering, and the problem of identifying such mixtures as specific oils at first seems insurmountable. It is this complexity, however, that permits identification of oils in the analytical laboratory; while certain similarities in molecular structure of Alkanes permit the quantitative analysis of oil in water. Alkane molecules are similar in that they contain only three possible configurations of carbon and hydrogen atoms: $-CH_3$, $-CH_2-$, $-\overset{|}{\underset{|}{C}}H$. The more complicated picture produced by the individual materials serves as the fingerprint of an oil, while the simpler molecular picture where the thousands of different materials (Alkanes) are presented in terms of their three basic building blocks, is used in the quantitative analysis of oil. Materials other than Alkanes that are also found in oil, usually in trace amounts include aromatics (molecules that resemble benzene); molecules that contain sulfur, called mercaptans or thiols; molecules that contain oxygen, some of which are called phenols; and molecules that contain nitrogen. Metals constitute one important group of trace materials; vanadium, nickel, and iron are of special interest. All these trace materials, together with the "fingerprints" produced by Alkanes, are used in the analytical laboratory to distinguish and identify oils.

Three laboratory instruments are commonly used to analyze oil: the gas liquid chromatograph, the infrared spectrophotometer, and the atomic absorption spectrophotometer. The gas chromatograph and atomic absroption spectrophotometer are used to identify individual oils, while the gas chromatograph, a very sophisicated distillation tool, permits the separation, from one another, of the thousands of different materials that make up oil. Individual materials are recorded as peaks on a chart; the height of each peak is proportional to the amount of material present. The overall graph that results is a fingerprint of the oil.

The atomic absorption spectrophotometer measures the trace metals in oil. This data is used to determine the ratios of iron, vanadium, and nickel that are present. These ratios vary among oils and help distinguish individual oils. The operating principle of this instrument derives from the ability of metals to emit and absorb light. The frequency of light emitted or absorbed identifies the metal, while the quantity of light is used to determine how much metal is present.

In the infrared spectrophotometer, a beam of light is passed through a solution of oil and the amount of of light absorbed at a specific frequency is precisely measured. This amount is proportional to the quantity of oil present. The greater the amount of oil in the path of the beam, the more light is absorbed. Infrared spectrophotometry is especially useful for quantitative analysis of oil because it yields simple recorded graphs that are mostly representations of the three basic carbon-hydrogen building blocks of Alkanes. Essentially, the "whole" oil is examined, rather than the individual materials that comprise it.

III PETROLEUM DISTILLATES

Many commercial products that are manufactured from oil are also spilled in our waterways. Most are made by distilling crude oil, and collecting fractions that boil within desired temperature ranges. Generally, higher boiling materials have larger molecules than materials that at lower temperatures; the thousands of materials in oil, therefore, boil over a broad temperature range. Those that boil at low temperatures are called volatile, while those that boil at high temperatures are called non-volatile. The materials in oil have a broad range of volatilities and yield a large number of different fractions during distillation. These fractions can overlap; for example, one fraction can boil between 100°C - 200°C, and another between 150°C - 250°C. Petroleum refineries designate fractions by different commercial names and market them as petroleum distillates; often without further treatment. Examples of such commercial products include light gasoline, a fraction that boils between -0.5°C - 150°C; kerosene, a fraction that boils between 151°C - 270°C; and No. 2 fuel oil, a fraction that boils 225°C - 360°C. Some of the non-volatile materials that remain are called No. 6 fuel oil, and asphalt. Although the physical properties of petroleum fractions often differ significantly from crude oil, they are very similar to oil, chemically. The analytical methods used in the laboratory to identify and quantitate distillates are essentially the same as those used to analyze crude oils.

IV SAMPLING

When sampling an area polluted by oil or a distillate, the type of laboratory analysis desired is an important consideration. If the required analysis involves the quantitative determination of a contaminant emulsified in water, it is important to reject any surface floating layer from the sample. The inclusion of this layer, which consists of essentially pure oil or distillate (1 million ppm), yields erronously high analytical results. A 1,000 ml (1.0L) portion of contaminated water is the preferred sample size for laboratory examination. If an identification of the contaminant is desired, however, it is best to provide the laboratory with a portion of surface floating layer. Such a sample is more representative of the pollutant and provides more material for analysis. A 100 ml (0.1L) portion of top layer is the preferred sample size for laboratory examination.

This outline was prepared by Michael Gruenfeld, Chemist, Oil Spill Research Section, R&D, Edison Water Quality Laboratory, Edison, New Jersey, 08817

ANALYSIS OF OIL SAMPLES

I INTRODUCTION

A Oils and oil-water samples are analyzed to identify the type of spilled petroleum product or to establish similarity between samples collected from the environment and from suspected sources. Common origin is probable if samples agree in their key characteristics.

B Analysis is complicated by effects of environmental influences and lack of procedure adapted to oil-water mixtures. Petroleum analysis is based upon procedures developed with petroleum products.

C Analysis of environmental samples involves preliminary cleanup followed by standard analytical procedures. The complete analytical sequence shown in Figure 1 involves three levels of activity.

1 Preliminary cleanup intended to separate the oil from the water and produce an organic phase amenable to analysis.

2 Identification of spilled material as a specific type of petroleum product; e.g., gasoline, jet fuel, crude oil, etc. Identification is accomplished by analysis according to standard procedure and comparison of results with prescribed characteristics of typical petroleum products. Characteristics of a few such petroleum products are specified in Table 1.

3 Further analysis more clearly defines the relationship between the environmental sample and reference samples collected from suspected sources. Results of the analyses are used to evaluate similarity.

D Both the apparent and suspected nature of the sample will influence the actual laboratory procedure. The analyst himself will normally select the procedures necessary to accomplish identification or comparison. The required level of analysis (e.g., identification or identification/comparison) depends on the nature of the problem.

II CLEANUP

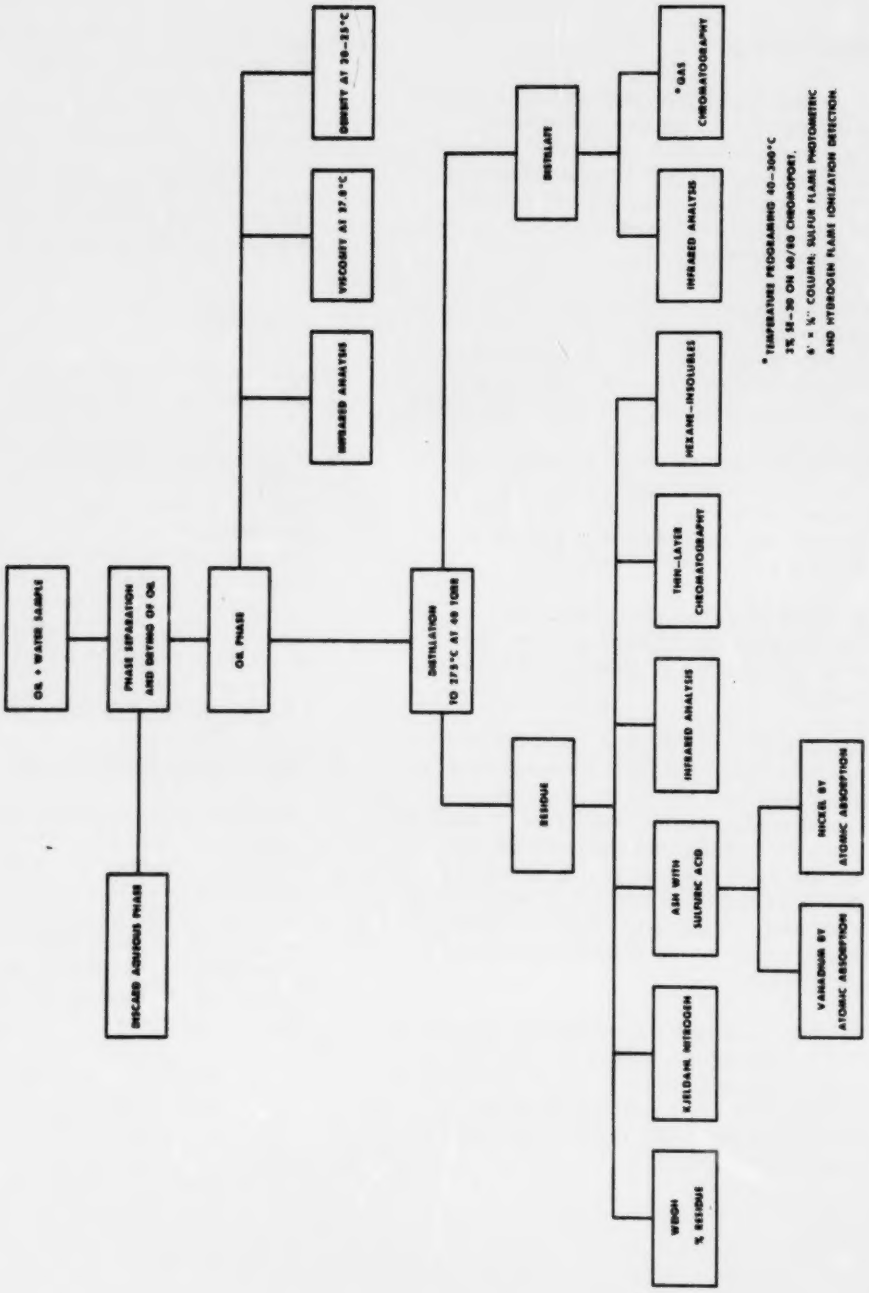
Sample cleanup is commonly accomplished by one of three basic methods:

A Simple Phase Separation is generally applicable to distillate fuel oils (Fuel oil nos. 1, 2, and 4, kerosene, gasoline, etc.), and consists of withdrawing the heavier aqueous phase from the lighter organic phase in a separatory funnel. The organic phase is then dried by passage through anhydrous $CaCl_2$. The dissolved petroleum products may be "salted out" of the aqueous phase by the addition of Na_2SO_4 to the water.

B Drying with Centrifugation

When the petroleum product is emulsified with water (as is the case with some crude oils and residual fuel oils), it is sometimes possible to break the emulsion by removal of the water from the matrix with anhydrous calcium chloride, and then centrifuging the sample in a chemical centrifuge to isolate the oil phase as the centrifugate.

ANALYTICAL SCHEME FOR CRUDE OILS


OIL + WATER SAMPLE
PHASE SEPARATION AND DRYING OF OIL
DISCARD AQUEOUS PHASE
OIL PHASE
INFRARED ANALYSIS
VISCOSITY AT 37.8°C
DENSITY AT 20–25°C
DISTILLATION TO 275°C AT 40 TORR
DISTILLATE
INFRARED ANALYSIS
*GAS CHROMATOGRAPHY
RESIDUE
WEIGH % RESIDUE
KJELDAHL NITROGEN
ASH WITH SULFURIC ACID
VANADIUM BY ATOMIC ABSORPTION
NICKEL BY ATOMIC ABSORPTION
INFRARED ANALYSIS
THIN-LAYER CHROMATOGRAPHY
HEXANE-INSOLUBLES

*TEMPERATURE PROGRAMMING 40–300°C
3% SE-30 ON 60/80 CHROMOPORT.
6' × ¼" COLUMN; SULFUR FLAME PHOTOMETRIC
AND HYDROGEN FLAME IONIZATION DETECTION.

FIGURE 1

TABLE 1

CHARACTERISTICS OF STANDARD PETROLEUM PRODUCTS

PRODUCT	API GRAVITY (API UNITS)	KINEMATIC VISCOSITY (centistokes)	DISTILLATION RANGE (I.B.P. - E.P.)	COMMENT
High Gravity Naphtha	45 - 75		95° - 206° F	Sulfur 0.02%
Low Gravity Naphtha	30 - 53		160° - 410° F	
Gasoline	58 - 62		96° - 408° F	Contains lead, halogens
Jet Fuel	40 - 55		100° - 500° F	
Kerosine	40 - 46		355° - 575° F	Narrow API Gravity range
Fuel oil #1	> 35	1.4 - 2.2		
Fuel oil #2	> 26	< 4.3	370° - 675° F (90%)	Sulfur exceeds 0.5%
Fuel oil #4	9 - 36	5.8 - 26.4	420° - 683° F	
Crude Oil	13.5 - 33.5	2.3 - 10.5	40° - > 850° F	Wide dist. range
Fuel Oil #6	-2 - 18	> 100	> 700° F	

C Phase Separation with Solvent Addition is accomplished by adding a solvent, such as chloroform to the oil-water mixture. It is sometimes possible to obtain a clean phase separation by solvent addition and to proceed as in A to separate the organic phase from the aqueous. The organic phase, after drying with calcium chloride, is heated to evaporate the solvent.

III IDENTIFICATION

A When cleanup has been completed, the separated and dried organic phase, is subjected to analysis. Identification is normally accomplished by comparison of sample characteristics to those of typical petroleum products. Characteristics of a few typical products are specified in Table 1.

B The analyses indicated in Figure 1 should be considered alternatives which the analyst may select to accomplish identification. Only a few analyses may be required in some cases, whereas in other cases the complete analytical scheme may be necessary. It is the responsibility of the analyst to select the combination which will accomplish the most certain identification in the time available.

C Analytical Parameters

1 Solubility in organic solvents - Used to differentiate greases and asphalts from other petroleum products, and to distinguish between crude oils and residual fuel oils from different locations. Table 2 gives solubility characteristics for several typical petroleum products.

2 Specific gravity or API gravity - The gravity or density is a distinguishing characteristic of oils. However, since the loss of volatiles, which occurs in the early stages of environmental exposure with volatile distillate fuels and crude oils results in an increase of this parameter, it is of limited value.

TABLE 2

SOLUBILITY OF PETROLEUM PRODUCTS IN ORGANIC SOLVENTS

	Solvent	
Product	Hexane	Chloroform
Light Naphtha	VS	VS
Heavy Naphtha	VS	VS
Gasoline	VS	VS
Jet Fuel	VS	VS
Kerosene	VS	VS
Cutting Oil	S	S
Motor Oil	S	S
Paraffin Wax	S	S
White Petroleum Jelly	PS	PS
Grease	I	S
Residual Fuel Oil	PS	S
Asphalt	I	S

VS = very soluble
S = soluble
PS = partly soluble
I = insoluble

3 Infrared spectroscopy - Indicates the relative content of aromatic or carbon-ring-type compounds. May also indicate presence of additives such as silicones. Generally employed to characterize materials less volatile than #2 fuel oil, such as #4 and residual fuels.

4 Average molecular weight - Used to identify low and high boiling products. Not commonly employed with other than pure hydrocarbons.

5 Distillation range - Defined as the temperature difference between high

and low boiling compounds in an oil observed during distillation. Actual procedures are specified by ASTM D 86-56, ASTM D 850, and ASTM D 216. Reported as the actual temperatures at which distillation begins and ends: (1) I.B.P., initial boiling point, and; (2) E.P., ending boiling point. The boiling range relates to volatility. Although potentially valuable, IBP is useless if the oil has been subjected to weathering before collection due to volatilization of lower boiling components. Typical distillation ranges are presented in Table 1.

6 Viscosity - A measure of the resistance to flow. May be expressed as (a) Saybolt second units (SSU), the time required for a standard volume of oil to pass through a standard orifice, as specified by ASTM D 445-53T and ASTM D 446-53; (b) kinematic viscosity at 100° F or 212° F in centistokes (ASTM D 445-65) or in Saybolt Furol units at 122° F. ASTM 2161-63T gives the relationships between the different viscosity units.

7 Distillation - As a loss of volatile components (if present) occurs on environmental exposure resulting in an increase of the remaining components, these may be put on the same basis (normalized) by distilling all samples to a similar degree. This is accomplished in our laboratory by distillation in a simple distillation apparatus to obtain a distillate boiling point of 275° C at 40 mm Hg pressure. The distillate is analyzed by gas chromatography and the residue for vanadium, nickel, sulfur, and nitrogen content and infrared analysis. Column chromatography may be incorporated in the analysis.

8 Vanadium is analyzed according to ASTM D 1548-63.

9 Nickel is analyzed either in the final solution from the vanadium procedure by atomic absorption (AAS) or by dissolving 5g oil in 100 ml of xylene for determination by AAS.

10 Sulfur is analyzed by the procedure described in ASTM D 1552-64, using the Leco induction furnace, or by ASTM D 129-64, utilizing an oxygen combustion bomb. In domestic fuel oils (1967), sulfur values ranged from 0.001 to 0.45% for #1 fuel oil; 0.02 to 1.6% for #2 fuel; 0.2 to 3% for #4 fuel oil; and 0.4 to 4.25% for #6 fuel oils.

11 Nitrogen is determined by the Kjeldahl method.

IV SUMMARY

Oil analysis involves three levels of laboratory activity: sample preparation and cleanup; basic identification; and final comparison. Identification as a petroleum product is accomplished by comparison of sample characteristics to prescribed properties of typical products. Further analysis may be performed to more firmly establish the similarity between environmental samples and reference samples collected from potential sources. At all stages of analysis the judgement of the analyst is crucial. Typical analyses include observation of solubility in organic solvents, infrared spectroscopy, API Gravity, distillation range, gas chromatography, specific metal determinations, viscosity measurement, and sulfur determination.

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This outline was prepared by L. Kahn, Chief Chemist, Laboratory Branch, Edison Water Quality Laboratory, Office of Water Programs, Edison, NJ. 08817.

FATE AND BEHAVIOR OF SPILLED OIL

I INTRODUCTION

The tar-asphalt residue of the "weathering" of oil is a product of a complicated multi-process phenomenon. The main processes in roughly the order of occurrence after a spill are spreading, evaporation, dissolution and emulsification, auto-oxidation, microbiological degradation, sinking and resurfacing after which the process repeats itself. While these processes are occurring, the slick may also be moving.

II MAJOR PROCESSES IN THE DEGRADATION OF OIL

A Spreading

This process, the first to occur, thins the slick out to a few millimeters or less and is dependent on several parameters--among them, viscosity of the oil, surface tension of the oil and water, and time.

B Evaporation

Evaporation is the process by which the low molecular weight compounds of relatively low boiling point are volatilized into the atmosphere. The rate of this process is also governed by many parameters--among them are viscosity of the oil, type of oil, and weather conditions, such as wind and sea state. The major loss due to evaporation occurs during the first few days.

C Dissolution

Dissolution is the process by which the low molecular weight compounds and polar compounds are lost by the oil to the large volume of water under and around it. The rate of this process is also governed by many parameters including the type of oil, viscosity of the oil, the amount of oxidation the oil has undergone before, during and after the spill and the weather conditions such as wind, and sea state. Although this process starts immediately, it is a long term one and continues throughout the duration of the total weathering process since the oxidation and microbiological degradation processes constantly produce polar compounds which are finally dissolved in the water.

D Emulsification

Emulsification is the process by which one liquid is dispersed into another immiscible liquid in droplets of optically measurable size. In the case of oil, the emulsion can be either an oil-in-water emulsion or a water-in-oil emulsion.

E Auto-Oxidation

Auto-oxidation is the light catalyzed reaction by which hydrocarbons react with atmospheric oxygen to form ketones, aldehydes, alcohols and carboxylic acids which are all polar compounds and, therefore, can either dissolve in the water or act as emulsifying agents or detergents.

F Microbiological Degradation

Microbiological degradation is a multi-faceted process. Certain bacteria, actinomycetes, filamentous fungi, and yeasts utilize hydrocarbons and chemically oxidized hydrocarbons as food sources.

1 Aerobic microbial oxidation

Most of the microorganisms which oxidize hydrocarbons require oxygen in either the free or dissolved form. When the oxidation of the oil occurs at the air-water interface there is usually sufficient oxygen to allow the maximum biological degradation to occur. However, areas of activity beneath the surface in the water column or in bottom muds are severely limited by the supply of oxygen.

2 Anaerobic microbial oxidation

A few organisms are known which oxidize hydrocarbons when little or no dissolved or free oxygen is present. These utilize nitrate or sulfate as their oxygen source. "Psuedomonas aeruginosa", for example, utilizes n-octane or n-hexadecane while reducing nitrate to nitrite. Many sulfate-reducing bacteria are known.

G Sinking

Evaporation, dissolution and oxidation of lighter hydrocarbons may cause the oil to increase its density. When this happens to a sufficient degree the oil will sink to the bottom where anaerobic microbial oxidation will be the main process of degradation.

H Resurfacing

If the density of the oil mass is reduced to a sufficient degree by anaerobic oxidation, the oil will float again and the processes above will again occur until the oil has either completely disappeared or has reached some land mass.

III PHYSICAL MOVEMENT OF OIL SLICKS

In the absence of current or debris, an oil slick will move in the direction of the wind at a rate about 3-4 percent of the wind velocity. In the absence of wind or debris, an oil slick will move in the same direction with the same speed as the water current. The actual movement will be due to some combination of wind and current.

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This outline was prepared by Dr. J. Lafornara, Research Chemist, Edison Water Quality Laboratory, OWP, EPA, Edison, New Jersey 08817.

BIOLOGICAL EFFECTS

Part I

I INTRODUCTION

The most obvious conclusion reached from viewing a major oil spill that has effected the natural plant and animal populations is that oil and biota do not mix! Dead and dying creatures are in evidence along the shore and on the water surface.

II DIRECT TOXIC EFFECTS (ACUTE)

Dead animals exhibit the direct toxic effects of petrochemicals.

A Suffocation

Death occurs when the organisms are coated by a layer of oil that interferes with their mechanisms for obtaining oxygen and the creatures die of suffocation. In general, this includes the sessile and slow moving biota of the intertidal zone which have limited mobility to escape the oil slick.

B Narcosis and Necrosis

Organisms may exhibit the narcotic effects of soluble oil fractions in the water column. These soluble components are absorbed into the tissues of the animals, directly killing or weakening them. The weakened animals are less resistant to the strain of moving water and are easily washed from their point of attachment or otherwise killed.

III INDIRECT OR CHRONIC EFFECTS

Though an animal is not quickly killed by the components of an oil spill, adverse effects can still be detected.

A Tainting

The accumulation of compounds in tissues of commercially important organisms can lead to tainting, off flavors and human health hazards.

B Accumulation

Accumulation of chemicals from a sub-lethal concentration in the water can lead to a lethal concentration in the animal.

C Behavioral changes, such as rate of locomotion, onset of spawning, and efficiency of feeding can lead to adverse effects on a population of animals.

IV FACTORS AFFECTING TOXICITY

Several factors influence the effects that various materials will have on the biota.

A Chemical

The compounds themselves have different toxic properties, solubilities, and are variously absorbed and degraded.

B Exposure

Exposure is important and varies with time of exposure, concentration, and synergistic effects, the last including other pollutants as well as the physico-chemical properties of the water.

C Biological

The effect on the organisms varies with the species of the organisms, life stages present, time of the year and previous acclimation conditions.

V REMARKS

In general, there are many variables to weigh when determining the effects, or possible effects, of an oil spill and means to combat the spill. The effect on the biota should be one of the first, if not the first, aspect to consider when setting priorities.

BIOLOGICAL EFFECTS

Part II - Damage Assessment

I INTRODUCTION

Sampling of the biota during and after an oil spill is necessary to assess the extent of biological damage. Logistic factors to consider are the type of communities to be sampled, the legal aspects involved, and the time, personnel and equipment available.

II SPECIFIC COMMUNITIES

A Open Water

Sampling the open water community consists of a sample of the oil slick, surface and subsurface samples of the water (Kemmerer and bucket), and plankton samples (Clark-Bumpus, tow nets, hand held plankton net).

B Intertidal

Intertidal communities are classed as rocky shore, sandy shore, or mud flats. Supra-littoral and mid-littoral sampling consists of hand picked and subsurface samples quantified to a known area. Sub-littoral samples are taken quantitatively by benthic samplers (Eckman, Peterson, orange peel).

C Salt Marsh

When salt marsh communities are affected, the plants can be sampled by clipping the high and low meadow vegetation from known areas. Soil and exposed mud surfaces are sampled removing soil plugs of known areas. The biota is best sampled by hand picking from known areas.

III FOLLOWUP SURVEYS

A Biological

Followup surveys are needed at various times after the initial mortality. Collections should be made daily until the delayed mortality has stopped. Thereafter occasional samples, on perhaps a monthly basis, should be made to to determine the rate of recolonization and any changes in species composition from the original state.

B Extension of Affected Area

Oil deposits will move through the sediments and enlarge the affected area, so surveys of the sediments and biota should be made to determine the extent of the submerged oil and its affect on the biota in the extended areas. An estimate of the affected area, both originally and subsequently, is necessary to assess total damage.

IV PRESENTATION OF DATA

The data of the damage to the biota is expressed as the percent of each species killed per unit area (usually per meter^2), as well as total numbers live and dead. The content of a hazardous material in the body tissues is expressed as parts per million per gram of dry body weight. Recolonization data is presented as numbers of organisms of each species per unit area.

V REMARKS

A Sample each habitat to get the full range of species present. Several quantitative samples may be necessary to be representative.

B Collect all stages of mortality present, dead though unaffected, if possible.

C If feasible, maintain some organisms alive by use of holding facilities or ice.

D Proper preservation and containers depend on the analysis to be conducted.

E Legal procedures must be followed for labeling and change of custody records if a court case is to be involved.

BIOLOGICAL EFFECTS

Part III - Bioassay

I INTRODUCTION

The use of bioassays have essentially been limited to specific problems and only recently have attempts been made to standardize procedures. Comparisons can be made only roughly between bioassays performed in the past due to the variety of organisms utilized and the lack of specific procedures.

II TYPE OF SYSTEMS FOR BIOASSAY

A Static

Systems employing containers of standing water, test substances in several concentrations, and a constant number of test organisms are static bioassays.

B Flow-Through

Systems meeting the above parameters, but with the water and test substance being constantly replaced at a known rate, are flow-through bioassays.

C Monitoring

Organisms placed in water from a suspected source, or placed in porous containers suspended in a suspected body of water, constitute a type of bioassay used for monitoring a specific problem.

III CHOICE OF ORGANISMS

A Desirable Attributes

Organisms used in a bioassay need to be readily available, whether captured from the wild or artificially cultured. For convenience, they should be of a small size and easily handled, but should be relatively sensitive. By using several species, phylogenetic diversity can be attained and these should be ecologically significant.

B Variability Sources

Inconsistent results in a bioassay can be found in size, age, sex, and species or variety differences in the test organisms. Water quality, conditions of acclamation, previous treatment, and presence of disease or parasites can cause problems.

C Problems in Organism Standarization

Species, or sets of species, having all of the desirable attributes and few of the undesirable ones are scarce. In the past, investigators have tended to use those that are readily available, regardless of availability to other investigators, susceptability, or of ecological significance. Universal availability and sensitivity seem to be the hardest criteria to meet.

IV CALCULATION OF TL_{50}

Toxicity is expressed as the concentration that has been determined as able to kill one-half of the test organisms in a given period of time and is expressed at TL_{50} in ppm. The "TL" refers to "tolerance limit" and the "50" signifies the 50% mortality level. After graphing percent mortality vs. concentration of the solutions, a line is followed from the 50% mortality point on the mortality axis to the plotted line, then to the concentration axis to determine the concentration that corresponds to this mortality level.

V INFORMATION GAINED

A Relative Tixicity

An estimate of the level of toxicity of a substance can be determined by bioassays and general comparisons can be made between compounds.

B Application

Toxicity levels can aid in setting water quality standards on bodies of water receiving effluents, determining "safe" levels of discharges, to assess damage for court cases, and to aid decision-making on how to handle an accidental spill.

BIOLOGICAL EFFECTS

Part IV - Biological Fate

I INTRODUCTION

The ultimate desirable fate of oil from a spill is its breakdown to carbon dioxide and water. Some oil will enter the food chain as unmetabolized hydrocarbons, but here we are concerned with degradation. The bacteria derive energy from petroleum by the action of enzymes on specific sites on the molecules, and produce carbon dioxide and water as end products. As with other media, the petroleum is converted to bacteria biomass which must later be decomposed. The increase of cell numbers with time in a newly innoculated culture is represented by a log curve with log, lag, and stabilization phases.

II NATURALLY OCCURRING BACTERIAL POPULATIONS

A Uncontaminated Areas

Because of the specificity of bacteria and the low occurrence of oils in an uncontaminated area, few petroleum-degrading bacteria are found under normal circumstances.

B Contaminated Areas

In areas where oil spills and seeps are found, these types of bacteria can establish dense concentrations.

C Limiting Factors

Some of the limiting factors which affect bacterial growth are temperature, salinity, gas tension, pH, nutrient supply, depth, incident light, and the accumulation of metabolites.

III SEEDING OF OIL SLICKS

A Rationale

Seeding of oil spills with commercially prepared cultures is potentially an effective means of oil spill cleanup. Partial degradation of the oil slick decreases the amount of oil which can sink and incorporate in the sediments. Areas difficult to reach by mechanical devices or sorbents can be cleaned of adhering oil films as well as the last traces of oil that mechanical devices or sorbents fail to pick up. In areas of potential biological damage, seeding may be desirable to remove the oil without causing additional and undue mortality.

B Advantages

Seeding may decrease the lag time in the bacteria's growth curve and supply several previously scarce species that will degrade oil. This would tend to increase the rate of degradation of the spill and possibly decrease limiting metabolites. In general, this would not only remove the oil but would decrease the time that oil would be free in the environment.

C Disadvantages

Cultures of oil degrading bacteria may contain human pathogens and thereby present a health hazard. The expense of the cultures and their applications may be excessive for the benefits returned. Die-off of large numbers of bacteria may lead to low dissolved oxygen levels in localized areas, especially where water circulation is limited.

This outline was prepared by Royal J. Nadeau, Ph.D. and Thomas H. Roush, Aquatic Biologists, Oil Spill Research Section, R&D, Edison Water Quality Laboratory, Edison, NJ 08817

OIL SAMPLING

I INTRODUCTION

A A complete oil sampling program is undertaken for the primary purpose of presenting legal evidence in a court of law. To protect the interests of all parties concerned three basic sampling requirements should be observed:

1 The sample must represent that oil which was spilled.

2 The sample must not be physically or chemically altered by the collection procedure.

3 Transfer of the sample must be accomplished using a well defined chain of custody system.

B The two basic types of oil sample analysis are:

1 Qualitative - to determine the presence or absence of oil and to compare the sample to a suspected source.

2 Quantitative - to determine the amount of oil present at the spill site.

Collection for qualitative analysis greatly exceeds collection for other purposes. For this reason, alternate methods are under study which will detect the presence of oil without the requirement for physical sampling. These methods will use photographic and electronic sensors and include:

1 Earthbound instrumentation

2 Airborne instrumentation

Earthbound instrumentation would be deployed in areas of high probability of spills such as in harbors and near terminals and refineries. Airborne instrumentation, on the other hand, would allow occasional spot checks of other areas and effective monitoring of cleanup operations. Ideally, such instrumentation should be capable of detection, identification and of providing aerial and thickness measurements.

Methods for tagging oils are also under study. These methods are grouped into two categories:

1 Active tagging

2 Passive tagging

Active tagging requires that an inexpensive, coded material be added to oil. This material must be chemically and physically stable in both oil and oil slicks. It must be readily identifiable by available analytical techniques and it must have no adverse effect on the oil's subsequent use.

Passive tagging assumes that oils are so chemically diverse that their contents constitute a stable chemical fingerprint that can be unequivocally disclosed by laboratory procedures.

Sampling for quantitative analysis is extremely difficult due to variations in slick thickness over the spill area. For this reason experienced, visual observation will generally provide more reliable information on the quantity of oil spilled. Table I is a guide for estimating the amount of oil on the water's surface.

II SAMPLE DETERMINATION

A The ideal sampling program is one in which collections are made BEFORE and AFTER the spill incident. The very nature of an oil spill, however, generally precludes "BEFORE" sampling.

B The types of samples to be collected depend on the following parameters:

1 Location of the spill

a Offshore

b Harbor areas

c Inland waters

2 Uses of the area involved:

a Drinking water source

b Shellfish growing area

c Wildlife refuge

d Finfish spawning area

e Recreation

f Commercial fishing

3 Facilities available for analysis:

a Qualitative analysis

b Quantitative analysis

c No analysis

4 Source of spill

a Offshore platform

b Refinery

c Terminal operation

d Storm drain

e Ship - in port
- offshore

TABLE I

Appearance of Slick	Amount of Oil
Barely discernible	25 gal/sq. mi.
Silvery sheen	50 gal/sq. mi.
Faint colors	100 gal/sq. mi.
Bright bands of color	200 gal/sq. mi.
Dull brown	600 gal/sq. mi.
Dark brown	1,300 gal/sq. mi.

C Qualitative analysis is performed to determine the presence (or absence) of a particular type of oil. This analysis may be performed on samples of:

1 Water

2 Fish and shellfish

3 Mud

In addition to direct chemical procedures, two additional types of qualitative analysis may also be performed to detect the presence of oil in water, fish and shellfish samples:

1 Taste tests

2 Odor tests

It is emphasized that once a spill has occurred, qualitative analysis is useless without a source sample for comparison. That is, a representative OIL sample must be collected from the source, such as:

1 The ship - each compartment, bilge and ballast

2 Offshore platform

3 Terminal - each tank

4 Refinery - various process sources

5 Storm sewer - suspected sources

It may also be desirable to collect benthic, phytoplankton and zooplankton samples. However, this should only be done if BEFORE and AFTER samples can be obtained and only if a qualified staff or marine biologists are available for collection, preservation and analysis.

III SAMPLE COLLECTION

A Many precautions must be observed when handling oil samples for analysis since the character of the sample may be affected by a number of common conditions including:

1 Composition of the container--glass bottles should always be used since plastic containers, with the exception of teflon, have been found under certain conditions to absorb organic materials from the sample. In some cases, the reverse is also true in that compounds have been dissolved from the plastic containers into the sample itself. This problem also applies to the bottle cap liners; therefore, the portion of the cap that comes in contact with the sample should be made of glass, teflon, or lined with aluminum foil.

2 Cleanliness of the container--previously unused glass bottles are preferred. If this is impossible, bottles should be either acid cleaned or washed with a strong detergent and thoroughly rinsed and dried.

3 Time lapse between sampling and analysis--since the chemical characteristics of most oils, especially the lighter fuel oils, change with time, the time lapse between sampling and analysis should be kept to a minimum. If analysis cannot be completed within 24 hours, samples can be preserved, depending upon the volatility of the oil, by removal of air and exclusion of light. With heavier type oils, such as No. 4 and residual oils, carbon dioxide may be used to displace the air. If dry ice is available, (approximately 0.5 cu. in.) it may be added to the sample. As soon as the effervescing has stopped, the jar should be sealed. When carbon dioxide or another inert gas is not available, or in those instances where volatile components are present (No. 2 or lighter), the sample can be preserved by carefully filling the bottle to the top with water to displace the air. All samples should be kept under refrigeration until analyses are completed.

4 Collection of adequate volume of sample--it is desirable to obtain as much of a sample of the oil as possible. It is suggested that 20 mls be considered as the minimum volume of oil needed to perform a series of "identification analyses" on light oils--No. 2 and below. For heavier oils a minimum volume of 50 mls is required.

B Oil Sampling Techniques

Sampling of oil presents many difficulties not immediately obvious. An oil slick may vary in thickness from several inches down to a monomolecular layer measured in microns (10^{-4} cm.). The quantity of sample required is therefore important since such will determine the area of sweep. For example, 5,000 gallons of oil, if assumed to be evenly distributed over one square mile of water, will equate to an oil thickness of 0.0071 mm. If 200 ml of sample is found necessary, then all the oil must be recovered from 28 square meters of open water. If sampling recovery is 50 percent rather than 100 percent, the sweep area must be doubled. Table II below describes theoretical thickness and area, assuming an even distribution of oil for various magnitude oil spills.

TABLE II

OIL DISTRIBUTION ON A WATER SURFACE

Spill Area Gal/Sq. Mile	Spill Area ml/Sq. Meter	Area (Sq. Meters) Req'd to Obtain 200 ml/sample	Oil Thickness (mm)
1,000,000	1430	0.14	1.43
100,000	143	1.4	0.143
10,000	14.30	14	0.0143
5,000	7.15	28	0.0071
1,000	1.43	140	0.00143 = 1.43μ
100	0.143	1400	0.000143 = 0.143μ

C The ideal oil sampling device should contain the following characteristics:

1 Be simple to operate

2 Function under diverse conditions

3 Have a few moving parts and not require electrical power

4 Be inexpensive

5 Collect oil rapidly

6 Not require chemical treatment of sample

D Current Sampling Procedures

1 Manual Separation

Manual separation is the oldest oil sampling procedure. The method involves collection of oil-water mixture in a container followed by manual separation of the oil and water phases. Collection and separation is continued until about 1 pint of oil has been collected. The procedure is quantitatively inaccurate because of the crude nature of both the collection and separation steps.

a Collection devices have included:

1) Simple pail

2) Pail fitted with a bottom tap

3) Sliding plexiglass cylinder whose fall is controlled by a trigger

4) Dustpan with a stopcock fitted to the handle

b Separation procedure devices have included:

1) Manual decantation

2) Separatory funnel

3) Glass filter funnel fitted with a two-way stopcock

2 Adsorbent materials

Many materials strongly adsorb oil and other hydrocarbons. Such materials include teflon shavings, straw, polypropylene fiber, rope, glass fiber, paper, and polyurethane foam.

Qualitative sampling requires contact of the sorbent with the oil followed by chemical (desorption) or physical (wringing or compression) recovery of the sorbed hydrocarbon. Quantitative sampling requires contact of the sorbent with a known area of liquid surface; this application has been impeded by variable and uncertain adsorption efficiency.

a French scientists have studied two applications of textured filter paper.

1) Free floating disks

2) Lined cylindrical containers

At film densities of 650 to 2200 mg/sqm (2.6 ml/sqm at a density of 0.85) both methods sample quantitatively to ± 25% with a single sample.

b Polyurethane foam

Adsorption by polyurethane foam appears to be a promising procedure. In practice a 1/4" × 1' sheet is simply dragged across the surface until apparent saturation is reached. The sheet is then passed through a wringer to recover the adsorbed oil.

When tested with South Louisiana crude oil this procedure recovered a sample containing less than 0.1 percent water. Infrared spectrographic analysis revealed no chemical differences between the original oil and the sample recovered.

IV DOCUMENTATION OF EVIDENCE AND SAMPLES

A Procedures for documentation of evidence and samples are specified by the National Oil and Hazardous Materials Pollution Contingency Plan and its regional derivatives. Collectively these plans guide the coordinated reaction of Federal, State, and local government and private agencies to uncontrolled discharges of hazardous materials. Documentation procedures include collection of samples from both the water course and suspected sources and preparation of a pollution incident report (Form FWPCA-209). These procedures have been established to document the actual facts of an incident and to protect the interests of all parties.

B After having been collected as outlined above each sample should be properly labeled using the chain of custody record, Form FWPCA-208 (See Figure 1). The record should contain the following information:

1 Sample collection data

This includes name and address of the agency submitting the sample number, data and time at which the sample was taken. A clear description of the source of the sample and the signatures of the sample collector and one or more witnesses. FAILURE TO OBTAIN THE SIGNATURES OF WITNESSES MAY RENDER THE SAMPLE LEGALLY INDEFENSIBLE. Witnesses should understand that by their signature they are certifying all information contained on the custody record, e.g., the date and time the sample was taken and description of its source.

2 Shipment certification

This information includes date and time the sample was submitted for shipment, the name of individual from whom it was received, the date and time it was dispatched, and the method of shipment, and the name and address of the consignee. All shipment information should be certified by an authorized representative of the common carrier or a postal official.

3 Certification of sample receipt

The individual receiving the sample should certify by signature the date and time of receipt, the name of the individual from whom the sample was received and the proposed disposition. If the sample is to be shipped to more than one laboratory, duplicate custody records bearing the same sample number should be completed.

C In accordance with procedures identified in the Regional Contingency Plan the on-scene commander should prepare four copies of the pollution incident report, Form FWPCA-209 (See Figure 2). Copies of the report and additional documents and attachments should be distributed as follows:

1 The original and one copy to the Chairman of the Appropriate Regional Operations Team.

2 One copy to the Joint Operations Team.

3 One copy to the Headquarters of the agency supplying the on-scene commander.

Three areas of the pollution incident report are especially crucial: Section III Pollution Data, Section IV Pollution Sample, and the first endorsement. As much data, facts, observation and information as possible should be included. All statements from persons directly concerned with the incident should be signed and witnessed. Although the on-scene commander may include other statements and comments, such information may not be entered as evidence.

V SUMMARY

A full scale oil sampling program is designed to collect samples, the analysis of which will be presented as legal evidence in a court of law. Qualitative and/or quantitative analysis will be performed on these samples which may include water, mud, fish and shellfish. What exactly is sampled depends on several parameters from the location of the spill to the analysis equipment available.

Sampling itself is more of an art than a science. Most methods are based upon manual collection in a container or adsorption and subsequent recovery. There is presently no recognized standard procedure.

Documentation of samples and evidence is required to adequately protect the interest of all parties to an incident. The conditions of collection, shipment and receipt of samples should be documented with utmost care to preclude later questions of validity.

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MICROBIOLOGY OF PETROLEUM

I INTRODUCTION

While the uses and collection of petroleum products was known to ancient peoples the implications of microbial interactions with these agents has only been explored for about a century. Concentration of efforts in the areas of Public Health and characteristics of individual microorganisms themselves preceded the study of many areas of value including the study of petroleum. Since the 1940's, however, increased needs, especially in the United States, has provided an impetus to this important field. The relative magnitude of this increase in interest can be seen from Table 1:[1]

At the present time the number of technologists directly concerned with petroleum microbiology in the world, while difficult to accurately enumerate, is at least fifty times greater than 20 years ago.

TABLE 1

SUMMARY OF PUBLICATIONS ON PETROLEUM MICROBIOLOGY

Period	Total Papers	Percent Published In United States	Percent Published In Europe
1875-1899	12	8	92
1900-1909	17	18	82
1910-1919	31	26	74
1920-1929	65	33	67
1930-1939	118	50	50
1940-1949	224	73	27

II THEORIES OF ORIGIN OF PETROLEUM

A Since the 1930's an immense amount of basic research has taken place regarding the environment and origin of source sediments of petroleum. Much of this research has been under the sponsorship of the American Petroleum Institute from privately subscribed funds. An abridgement, for brevity, of the more significant findings of this outstanding work, designated as a portion of APIs' "Project 43", is as follows (with this author's comments):

Finding	Comments
1. Biochemically diverse bacteria have been found in both ancient and recent marine sediments.	Indicates diverse groups present and naturally occurring. These studies were bacteriological in nature and it must be emphasized that microorganisms other than bacteria are capable of existence and interactions with petroleum.
2. Bacteria in abundance have been isolated from oil well fluids from depths of several thousand feet.	
3. Bacteria are most abundant in ocean bottom sediments and their numbers decrease as sediment is sampled in depth.	
4. Laboratory studies have indicated that certain organic compounds are modified in the direction of petroleum-like components.	These effects are still controversial as to their importance in nature.
5. Certain bacteria are capable of causing the release of oil from oil-bearing sedimentary rocks.	This microbial capability has generated much interest in the areas of oil prospecting and revitalizing depleted wells.

B At present there is a myriad of theories regarding the origin of petroleum and its formation is probably of a complex nature involving the interactions of many agencies. It is generally agreed, however, that the following are true regarding the transformation of organic matter into crude oil:

1 The formation temperatures were low and probably less than 150° C.

2 The formation pressures were relatively low.

3 Formed crude oil is a localized phenomenon.

4 The marine environment is the primary, if not the exclusive, forming site.

C Since numerous findings have established that petroleum products can provide a substrate for microbial activity with subsequent degradation of the original material, much controversy has resulted concerning the relative stability of petroleum stocks in the earth. Some possible explanations have been advanced as follows:

1 Lack or aerobic conditions due to reducing conditions deep within the earths' mantle.

2 Preferential breakdown of other compounds within the petroleum mass.

3 Presence of bacteriostatic substances (such as metallic ions, hydrogen sulfide, respiratory products, etc.) in the sediments, brines, and/or petroleum.

4 Interactions of these factors.

III MICROORGANISMS UTILIZING PETROLEUM AS A SUBSTRATE

The broad term microorganism is a general one which is meant to include all of the very minute living forms such as protozoa, bacteria, algae, yeasts, molds, etc. Recent compilations of the microorganisms capable of growing at the expense of hydrocarbons now total over 100 bacteria, yeasts, actinomycetes and fungi. Continuing studies of this nature have brought about the realization that the utilization of hydrocarbons is not limited to a few organisms and that, possibly, they can serve as routine substrates in taxonomic classifications.

Numerous genera of bacteria, actinomyces, and fungi, which are commonly found in soils, are capable of utilizing the wide range of hydrocarbons ranging from the paraffin, kerosene, gasoline, and lubricating and mineral oils to tars, asphalts, and natural and synthetic rubbers.

Primary emphasis has been, until recently, in the areas of investigations relating to the "problem organisms" and their detrimental effects upon the industry. Recent concern regarding treatment practices have ushered in a wide spectrum of microbiological investigations.

IV DECOMPOSITION OF HYDROCARBONS BY MICROORGANISMS

A Substrate Specificity

The utilization of a hydrocarbon or hydrocarbons by a specific microorganism does not imply that this substrate is either the sole source of energy that this organism is adapted to or one that is preferentially attacked for metabolism. In fact, as a rule of thumb, it can be stated that most hydrocarbon utilizing microorganisms will oxidize other energy sources in preference to the hydrocarbon, and, in fact, many will show an attenuation for the original hydrocarbon upon prolonged exposure to these other sources (carbohydrates, proteins, fats, etc.) of energy. Small amounts of these other energy sources, however, usually speed up the ability of the microorganism to oxidize the available hydrocarbon.

As a rule, aliphatic or paraffinic compounds are oxidized more readily than corresponding aromatic or naphthenic compounds. Long-chain hydrocarbons are more susceptible to oxidation than those of shorter chain length. Branched chain, or iso- compounds, are oxidized more readily than the normal or straight chained homologs.

B Physical and Chemical Factors

Among a host of factors which control the rate of petroleum oxidation four can be singled out as particularly important:

1 Surface area

The magnitude of exposed surface area to a large degree determines the rate of oxidation of the petroleum pool. Since petroleum is relatively insoluble in water its availability in large surface area exposures is minimal.

2 Moisture

This universal transport medium is vital in biological processes and its relative scarcity in most petroleum pools severely curtails the decomposition processes. In such situations as where water-petroleum interfaces are available, such as wastewater discharges, the situation is more conducive to oxidative processes and the bulk of microorganism growth and interactions occur at this interface.

3 Oxygen

This element is vital for the rapid oxidation of petroleum. In its absence the decomposition of petroleum can occur, under anaerobic conditions, at a much reduced rate.

4 Minerals

The principal requirements here are for available nitrogen, phosphate, sulfate, and other trace minerals. Some of these minerals may be lacking in the environment and the decomposition processes may be remarkably slow.

V SELECTED REFERENCES

Since microorganisms do not fit an unchanging pattern with respect to biochemical interactions, and, to avoid a "cataloging" of numerous genera of microorganisms, the following is presented to offer information on a wide range of interest of scientific investigation. Each of these individual study areas must be considered as an abstracting of a published paper, which should be consulted for a complete treatment, which is utilized, for purposes of this outline, to offer an insight to some studies on the wide spectrum of hydrocarbon products.

A Survival of Bacteria in Cutting Oils[2]

The presence of bacteria in cutting oils is undesirable since they can: (1) interfere with desired qualities; (2) form objectional odors; (3) contribute to dermatitis and infections; (4) contribute to corrosion; and (5) in certain oils form objectional discolorations and de-emulsification tendencies.

In this study thirty different species of bacteria were tested for their survival times in nine different cutting oils. Gram negative bacteria were capable of surviving for considerable periods of time while the Gram positive bacteria were soon killed. Medium straight and emulsion type cutting oils permitted survival of the bacteria for longer periods of time than the heavy straight type cutting oils.

B Microbiological Sludge in Jet Aircraft Fuel [3]

This study was undertaken by the author due to equipment malfunction and difficulties in line aircraft of the U.S. Air Force. Initial experiments were designed to follow-up on the guide lines previously established at the author's laboratory (Bakamauskas [4], 1948): (1) establish the presence of microorganisms in the sludge; (2) isolate the bacteria in pure culture; (3) establish whether or not the bacteria could cause sludge; (4) determine whether or not approved corrosion and gum inhibitors, normally added to the fuel, were bacteriostatic agents; and (5) investigate selected water soluble, fuel insoluble, chemical compounds as bacteriostatic sludge inhibitors.....Many bacteria were isolated in pure culture from seven types of media. Further studies were conducted with the cultures characterized by rapid growth. Some of these produced very stable emulsions of the fuel and water; others produced gumlike residues in the water phase; and some produced objectionable water-soluble colorations.

Experiments involving the use of fuel-soluble inhibitors disclosed that these were, for the most part, unsatisfactory since at the usual prescribed concentrations they would either prove to be temporary in effect or totally lacking in bacteriostatic action to the isolated cultures. Some success was achieved with different control agents and continued research is in progress in this area.

C Microbial Degradation of Normal Paraffin Hydrocarbons in Crude Oil [5]

Fifty active oil degrading cultures were isolated in enriched seawater containing crude oil. Oil degradation was measured with gas chromatography, wet combustion, and by measurement of surface tension. Normal paraffin hydrocarbons through C-26 were degraded by two different groups of microorganisms--those growing in the oil phase only and those growing in the aqueous phase. Microbial degradation of 35 to 55 percent of oxidizable crude oil occurred within 60 hours.

D Reclamation of Soil Contaminated With Oil [6]

It is the general opinion that soil is never permanently sterilized by oil and that partial reclamation occurred naturally within about three years. The practice of aeration, fertilization, and manuring were definitely beneficial. These opinions were verified by growth chamber techniques using a variety of crops. The amount of oil that plants could tolerate was found to be species dependent suggesting another possible way to reclaim contaminated soil (previous literature indicates that small amounts of oil were innocuous and a conservative estimate of 1 kg oil/sq mile of surface area being the point where plant damage begins.)

Use was made of the bacteria Cellulomonas sp. to seed soil and hasten decomposition of oil. This method was effective at high levels of oil contamination using the criteria of CO_2 evolution and seed germination. Seeding with microorganisms supplied with nutrients significantly increased the rate of soil reclamation over the use of fertilizer alone.

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OIL TANKER OPERATIONS

I INTRODUCTION

Today's world tank ship fleet amounts to about 4000 ships with a total dead weight tonnage of 170 million long tons. Only about 400 ships are American registered.

These tankers range in tonnage from 2000 tons to 312,000 tons and Japan, the world's largest shipbuilder, is building a 470,000 ton tanker.

Supertankers are a recent phenomena. The first 100,000 ton tanker went into operation in late 1959. Today there are over 200 tankers of 100,000 tons or greater in size and about 240 under construction. Only 22 percent of these tankers are owned by oil companies. Another 18 percent are owned by the governments of the world and the remainder are privately owned. These privately owned tankers are contracted for by the oil companies.

There are two basic trades; the crude oil trade and the oil products trade. The supertankers are used almost exclusively in the crude oil trade. Shifting of ships from one trade to another are infrequent, however, when they occur the tanks must be thoroughly cleaned especially for transfer from the crude to the products trade.

II SOURCES OF OIL DISCHARGED INTO SEA FROM TANKER OPERATIONS

A Bilge Oil: Is that oil which collects in the ship's bottom through seepage or leakage.

B Slop Oil: Is that oil/water emulsion which is normally collected in an aft center tank as the residue of tank cleaning operations.

C Overflows: An overflow of oil usually occurs during the loading or discharge of cargo and the transfer of cargo from one tank to another. This is usually caused by carelessness or inattention.

D Ballast Water: This is normally sea water taken into empty cargo tanks to give the vessel stability. The "empty" cargo tanks usually have a residue of oil in them.

E Collision or Groundings: Whenever a loaded tanker vessel is involved in a collision the result is usually a major discharge of oil into the surrounding waters. Groundings are the most common types of accidents but they do not usually result in major oil spills.

III TANK CLEANING OPERATIONS

A Surface Area: The inner surface of a cargo tank, if inspected closely, would be found to be rough, uneven and pock-marked with thousands of minute pore openings. The total surface area of the interior of the cargo tanks of a T-2 tanker is approximately eight and one half acres.

B Clingage: When a beer glass is filled and emptied a certain amount of the liquid adheres to the side of the container. This is the liquid required to "wet" the surface of the container. It will vary in amount as a function of its viscosity, temperature, volatility and the roughness and configuration of the container.

In the same way, a certain quantity of oil under fixed conditions is required to wet the surface of the tanks of a tanker. Under average conditions based on long experience, it has been found that this quantity varies from 0.20% to 0.40% of the cargo. A median figure might be 0.30%. This means that if 250,000 barrels of average oil cargo were loaded into a tanker and the tanker immediately pumped out, only 99.7% of the oil would be recovered in the shore tanks and 0.30% or 750 barrels would remain in the ship. The oil remaining in the ship would be found to be adhering to the tank surfaces with a very small portion laying in shallow puddles at the suction "bell mouths" in the tank and cargo piping.

C Butterworth System: An operation of great significance in connection with the waste oil resulting from tanker operation is the system used for cleaning or washing down the tanks. Until the early 1930's, the cleaning of tankers was accomplished by long periods of steaming followed by hand washing with streams from fire hoses. There was then developed a system for machine washing of the tanks consisting of opposed revolving nozzles connected to a hose lowered to various levels in the tank to be washed. These nozzles revolve around both a vertical and horizontal axis by the action of a water turbin driven by the washing water at a pressure of about 160 pounds per square inch and a temperature of 170 to 180° F. This is known as the Butterworth System.

IV LOAD ON TOP PROCEDURES

A Background: Shell introduced the 'load-on-top' system in 1962. Other major oil companies soon followed, and today, encouraged by the oil industry, about 75 percent of the world's crude oil tankers practice the technique. Refineries of the major oil companies accepted 'load-on-top' residue after an experimental period in which they proved to themselves that the residue can be processed through the refinery unit--if it is less than 1 percent of the total crude cargo, and if the water content of the residue is less than 0.15 percent of the total cargo. The main problem facing the refinery operator is the removal of salt from the small amount of sea water discharged with the residue. The problem of the tanker operator, then, is to remove as much water as possible from beneath the oil--without discharging the oily waste itself.

B Principles of System: What are the principles of the Load-On-Top system? This is best described by Kluss [1]:

In the 'load-on-top' system, tanks are washed in this way during the ballast passage. The tank washing residues are accumulated in one tank. Most of the clean water in this tank is then carefully drawn off the bottom of the tank and discharged overboard, discharge being halted whenever oil traces appear in the water stream. The tank is allowed to settle, the oil wastes in the tank separate and float to the surface, and additional water is repeatedly withdrawn carefully from the bottom and discharged as before from beneath the floating layer of oil. Heat may be applied to hasten the separation of oil and water. Some companies occasionally add a demulsifier as well. When all possible water has been withdrawn, the next cargo is loaded on top of the remaining residues in this tank. Usually, this one compartment is segregated from the remainder of the cargo during discharge. Then the segregated material can be directed, as the specific situation dictates, to the fuels processing side of the refinery, to the refinery slop system for ultimate recovery, or mixed with the rest of the cargo being discharged.

C Pitching Ship: In a rolling pitching vessel, this is no small task. It is estimated that the oil content of the water discharged into the vessel's wake from the 'load-on-top' tank is in the region of 200 ppm, slowly increasing to 400 ppm and finally rising momentarily to 5000 ppm at the shut-off point. A tanker decanting this residue will not pollute the sea. Even the momentary maximum of 5000 ppm is only half of one percent. The turbulence in the moving ship's wake would immediately dilute any oil to a tiny fraction of its original concentration. If a vessel experiences rough weather on its way to the loading port and the water in the 'load-on-top' is therefore not reduced to an acceptable level, fresh crude oil can still be loaded on top. But at the discharge terminal the mixture at the bottom of the tank must then be retained on board to be put through another 'load-on-top' cycle.

D PPM of Oil Discharged - "Eyeball Method": 'load-on-top' is a questionable first step in the prevention of pollution of the sea by oil. There are many questions left unanswered. Members of the oil shipping industry admit that, at present, the best method of measuring the PPM of oil in an oily water discharge is by the "eyeball" method. This means that a member of the ship's crew must constantly watch the overboard discharge until black oil is seen with the naked eye. The crew member then signals to the pump man who in turn starts closing the discharge line. This may take from fifteen to thirty seconds. In the meantime, a significant amount of oil is lost overboard. In the 'load-on-top' paper, the author admits that at times, the discharge of oil waste into the sea reaches a height of 5,000 PPM.

E Emulsions: The basic problem of the 'load-on-top' system is the question, "how much oil is contained in the water being decanted into the sea?"

Emulsions take either one of two forms--an oil in water emulsion or a water in oil emulsion. The latter, of which the famous "chocolate mousse" is formed, is much more difficult to break than the former. The oil industry as a whole, has spent literally millions of dollars trying to separate oil from their wastewater discharge. This is still a major problem in the industry today. If the sophisticated oil/water separators of the major refineries cannot successfully remove all of the oil from an effluent discharge, how can we believe that a simple type gravity separator on board a rolling ship can effectively accomplish this?

V TANKER TERMS

A Gross Tonnage: One hundred cubic feet of permanently enclosed space is equal to one gross ton-it has nothing whatever to do with weight. This is usually the registered tonnage although it may vary somewhat according to the classifying authority or nationality.

B Net Tonnage: This is the earning capacity of a ship. The gross tonnage after deduction of certain spaces, such as engine and boiler rooms, crew accommodation, stores, equipment, etc. Port and harbor dues are paid on Net Tonnage.

C Displacement Tonnage: This is the actual weight in tons, varying according to whether a vessel is in a light or loaded condition. Warships are always spoken of by this form of measurement.

D Deadweight Tonnage: The actual weight in tons of cargo, stores, etc. required to bring the vessel down to her load line, from the light condition. Cargo deadweight is, as the name implies, the actual weight in tons of the cargo when loaded, as distinct from stores, ballast, etc.

E Innage: That space occupied in a product container.

F Outage: Space left in a product container to allow for expansion during temperature changes it may undergo during shipment and use.

G Ullage: That amount which a tank or vessel lacks of being full.

VI SINGLE POINT MOORING SYSTEMS

The tankers in the world fleet are growing bigger each year while the ports serving these supertankers are still in the World War T-2 class. The industry, therefore, advocates the Single Point Mooring System.

A Conventional Mooring System: The conventional mooring system uses fixed mooring buoys plus the fore and aft anchors of the vessel to be moored. The connecting hose to the underwater pipeline is connected to a small floating buoy, which is retrieved when the ship is in a fixed position. The known objections to this system are: (1) the vessel cannot remain in this position in rough weather, and (2) when the weather turns bad, it takes too long for the ship to un-moor and lift anchors.

B "T"-Jetty Mooring System: Some of these jetties are as long as 6,000 feet. The "T" head at the end of the jetty can be constructed to berth as many as eight tankers simultaneously. One of the advantages of this type of installation is that four pipelines can service six to eight berths simultaneously. The disadvantages of this type of installation are:

1 Extremely expensive to construct.

2 Ships must stop off-loading during bad weather, and slip moorings.

3 Approach speed to the installation for large tankers can only be at 1/10 knots. The problem here is that tankers personnel cannot sense true speed during approach and if the vessel strikes the installation at speeds over 3/10 of a knot, a large amount of damage can be expected. A new experimental radar system is being tried to overcome this objection.

C Sea Island Mooring System: This system has the same advantages and disadvantages as the "T"-Jetty Mooring System. In the Sea Island System the oil can either be pumped ashore through underwater pipelines or the oil can be stored on the island to be later trans-shipped to shore installations by smaller tankers and barges.

D Single Point Mooring System: While the Single Point Mooring is relatively new in the oil industry (1959), this system is gaining a widespread acceptance throughout the industry as a reasonable cost expense and an effective method to off-load or on-load a tanker. The Single Point Mooring System can handle tankers in much rougher weather than any of the aforementioned systems. One of the great advantages of this type of system is that the wind, high seas and tide forces straining against the ship is only 1/6 of the forces received at other mooring systems. This is due to the fact that the ship "weathervanes" around the Single Point Mooring System buoy, bow forward. At the present time, the industry considers the Single Point Mooring System as the next best thing to a harbor mooring. Shell Oil Company and IMODCO of California are the only two producers of SPM Systems at the present time. However, Standard Oil Company (N. J.) is in the process of patenting and constructing an SPM System utilizing a single anchor mooring which they believe will be superior to the present system. This SPM System, considered a third generation type, will have an underwater swivel joint. This buoy will have a rigid type conduit from the sea floor to a swivel connection approximately 70 feet below the water surface. When there are sufficient numbers of SPM buoys throughout the world, tankers will convert to bow loading manifolds. The cost of conversion to this type of loading will be approximately $70,000 per tanker.

VII FUTURE IMPROVEMENTS TO TANKER OPERATIONS

Because of world concern regarding oil pollution of the sea, governments of the world under United Nations sponsorship are meeting to discuss ways of improving tanker operations to reduce or eliminate oil pollution.

Four of these proposed improvements are:

A Limitation on tank size - this involves limiting tank sizes on all tankers to 30,000 cubic meters. It is now in the process of adoption.

B Compulsory installation of radar and bridge-to-bridge telephone - both are designed to reduce the occurrence of collisions and to improve navigation. Radar installation is now under discussion by various U.S. agencies. Congress has for approval regulations requiring installation of bridge-to-bridge telephones on all ships operating in navigable waters of the United States.

C Establishment of compulsory sealanes - discussions are now being held at the international level on adoption of sealanes. In some restricted waterways (Dover Straits) sealanes have been established.

D No deballasting at sea - proposed by the United States at various international conferences. Earliest adoption cannot be before 1975 and will likely be later. This would be the most preferred solution since deballasting, even with utilizing Load On Top, is considered the greatest single source of pollution.

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TREATMENT OF OIL SPILLS

DISPERSANTS

I BACKGROUND HISTORY

As far back as the early 1930's water emulsifiable degreasers were used. These degreasers were developed to answer the need for effective methods of cleaning oily and greasy surfaces. They possessed the properties of dissolving or dispersing in the grease or oil, and making the resultant mixture dispersible in water so that it could be flushed away with water.

The early products were composed mostly of soaps and solvents: The demands of the petroleum shipping industry required products that could be used effectively aboard ship with seawater. This led to the use of materials other than soaps as emulsifying agents because soap breaks down in seawater. Sulfonated petroleum oils and later more sophisticated synthetic detergents made their appearance in these products.

These emulsifying degreasers were widely used aboard ship for engine room maintenance, as well as for the clean-out of petroleum cargo tanks prior to welding repairs and prior to upgrading of cargo.

Because of their effectiveness in clean-out of oil residues it was natural that they should be tried for treating oil spills. In some cases they were incorporated in oil slops prior to dumping overboard to minimize slick formation.

There are presently over 200 commercially available products which are claimed useful for dispersing oil from the surface of the water. These products have been referred to as "soaps", "detergents", "degreasers", "complexing agents", "emulsifiers", and finally "dispersants". This latter term describes best what this type of product is intended to accomplish--the dispersion of oil from the surface into and throughout the body of water--and therefore is the preferred terminology.

II COMPOSITION

The primary components of dispersants are surfactants, solvents and stabilizers.

A Surfactants or Surface Acting Agents (SAA)

This is the major active component in dispersants.

By their affinity for both oil and water, surfactants alter the interaction between oil and water so that the oil tends to spread and can be more easily dispersed into small globules--or into what we commonly call an emulsion.

These agents are often defined according to their behavior in aqueous solutions. These solutions will usually wet surfaces readily, remove dirt, penetrate porous materials, disperse solid particles, emulsify oil and grease and produce foam when shaken. These properties are interrelated; that is, no surface active agent possesses only one of them to the exclusion of the rest.

SAA can be divided into two broad classes depending on the character of their colloidal solutions in water. The first class, ionic, form ions in solution, and like the soaps are typical colloidal electrolytes. The second class, the non-ionic, do not ionize, but owe their solubility to the combined effect of a number of weak solubilizing groups such as ether linkages or hydroxy groups in the molecule. A more detailed discussion of SAS is covered in reference (1).

Commonly used SAA in oil spill dispersants include soaps, sulfonated organics, phosphated esters, carboxylic acid esters of polyhydroxy compounds, ethoxylated alkyl phenols and alcohols (APE, LAE), block polymers and alkanolamides.

B Solvents

Since many of the surface active agents applicable to oil spill dispersant compounding are viscous or solid materials, some form of solvent is often necessary in order to reduce viscosity for ease of handling. In addition, the solvent may act to dilute the compound for economic reasons, to depress the freezing point for low temperature usage, to enable more rapid solubility in oil, and to achieve optimum concentration of surface active agent for performance reasons. The presence of a suitable solvent also serves to thin the oil to be dispersed, reducing viscosity and making it more easily emulsifiable. The solvent usually comprises the bulk of the dispersant product.

The three general classes of solvents used in oil spill dispersants are petroleum hydrocarbons, alcohols or other hydroxy compounds, and water.

1 Petroleum hydrocarbons

Petroleum fractions with boiling points above 300° F are usually used, and these may produce finished dispersants with flash points as low as 110° F. The proportion of aromaticity is of concern, since this effects solubility and emulsification properties as well as toxicity. Wardley Smith, Warren Springs Lab, UK, in describing the Torrey Canyon incident, reported that the aromatic solvents used were 10 times as toxic to marine life as were the surface active agents. Some typical fractions of applicable petroleum solvents include mineral spirits, kerosene, #2 fuel oil, and heavy aromatic napthas which contain significant quantities of higher alkylated benzenes.

2 Alcoholic or hydroxy group of solvents

Includes alcohols, glycols and glycol ethers. These solvents also lower the viscosity as well as the freezing points of finished dispersants. In addition, they furnish a co-solvent effect, often needed to mutually dissolve the various ingredients in a dispersant for stability of the compound in storage. This group of solvents may be used in conjunction with petroleum hydrocarbons as well as with aqueous solvent systems. Some of the more frequently encountered chemicals in this group include ethyl alcohol, isopropyl alcohol, ethylene glycol, propylene glycol, ethylene glycol mono methyl ether, ethylene glycol mono butyl ether, and diethylene glycol mono methyl ether. The more volatile members of the group are quite flammable.

3 Water

Least toxic, least hazardous and most economical of the solvents. It lacks solubility or miscibility with oils. Where water is used as the solvent, special problems exist in the choice of surface active agents and other additives in order to provide the necessary miscibility with oils. Glycols and alcohols are used to aid in miscibility as well as freezing point depression when water is used.

C Additives - Stabilizers

Third major component in dispersants, they may be used to adjust pH, inhibit corrosion, increase hard water stability, fix the emulsion once it is formed, and adjust color and appearance.

III DISPERSANT USE

A General

Dispersants theoretically serve to increase the surface area of an oil slick and disperse oil globules throughout the larger volume of water thereby aiding in accelerated degradation of oils by microbiological means. The chemical dispersants do not themselves destroy oil. They vary considerably in toxicity, effectiveness and ability to stabilize the oil after extended periods of time. Technology for proper application of dispersants over large oil slicks with necessary mixing is currently lacking. Use appears far more critical in harbor and estuary areas and in proximity to shore. Particular care must be exercised where water supply might be affected. The desirability of employing dispersants in the open sea remains unresolved although their use here (the ocean) is potentially more promising pending additional field data. After widespread dispersant use during major incidents, reports led to the conclusion that dispersants or the dispersant-oil mixture caused more damage to aquatic life than the oil alone. For beaches, they actually compounded the problem by adding to the amount of pollutants present, by causing the oil to penetrate more deeply into the sand, and by disturbing the sand's compactness, so as to increase beach erosion through tidal and wave action.

B Toxicity

Current information indicates that dispersants vary considerably in toxicity. The combination of oil and dispersant may increase the toxicity of either the oil, the dispersant chemical or both. The possibility of this "synergistic" action must be carefully examined before wholesale application of such a product is permitted. Dispersing of the oil, which has toxic components, may also compound the damage.

The toxicity of 40 dispersants, as reported by the Fisheries Laboratory, Burnham on Crouch, UK, is shown in Table I. It is important to point out that the dispersants used during the Torrey Canyon incident were mostly solvent based and highly toxic, killing marine organisms at concentrations of 10 mg/l. Chemicals available today are much less toxic.

C Application (2)

A common method of dispersant application is by the water eductor method. A controlled amount of dispersant is educted into a water stream such as a fire hose. This water jet is an effective vehicle or carrier for the dispersant and provides good coverage in treating the slick.

This application procedure however, while compatible with a water base system, may be imcompatible with a petroleum base system. This is because a dispersion of the petroleum solvent-in-water is formed as soon as the surfactant system is educted into the water stream. As illustrated in Figure 1 this accounts for the milky white appearance of the water after such applications. In this state, as graphically shown in Figure 1, it is difficult for the surfactant to transfer from its termodynamically stable location at the petroleum solvent-water interface to the oil spill-sea water interface. Therefore, for a petroleum base system, neat application of the chemical directly onto the oil slick is a more effective application method.

The prompt application of mixing energy after the dispersant (solvent or water base) has been applied is particularly important. In essence, small oil droplets must be produced while the immediate water environment is surfactant-rich.

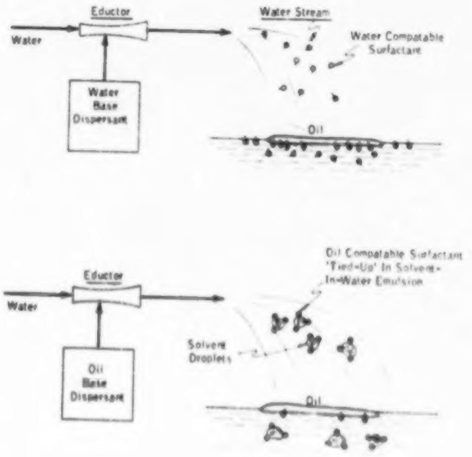

FIGURE 1

TABLE I(3)

Static Bioassays - TL_{50} 48 Hours @ 15°C (ppm)

Solvent emulsifiers	Pandalus montagui Pink Shrimp	Crangon crangon Brown Shrimp	Cardium edule Cockle	Agonus cataphractus Armed Bull Head	Flat Fish Pleuronectes limanda(L) or platessa(P) or flesus(F)	Asterias rubens Star Fish	Carcinus maenas Shore Crab	Ostrea* edulis Oysters
Gamlen OSR	12.5	8.8	15.8					
Polyclens	8.5	15.7	70				20.4	15- 50
Six	12.1	114.5	12.7				23.2	
BP 1002	5.8	5.6	81				> 300 (15)	≈ 100
Cleanosol	32	44	19.2		10-33 (L)		10-25	50-100
Essolvene	8.6	9.6	63				102	
Gamlen D	11.5	9.6	38.8				15-20	50-100
Gamlen CW	14.6		69.5					
Atlas 1901	87.2	120	48.5					
Slickgone 1	5.2	6.6	32.4				> 150	
Slickgone 2	4.5	3.5	30.5				35.0	
Shamash R1885	1-3.3	3.3-10					21.3	
Crow Solvent M		33-100						
DS 4545		≈ 1000						
DS 4545 in Pink Paraffin		330-1000						
DS 4545 in IPA		3300-10000	330-1000					
DS 4545 in IBA		330-1000						
Aquaclene		100-330	33-100					

*Tests lasted 5 days, not 48 hours.

TABLE I (Continued)

Solvent emulsifiers (continued)	Pandalus montagui Pink Shrimp	Crangon crangon Brown Shrimp	Cardium edule Cockle	Agonus cataphractus Armed Bull Head	Flat Fish Pleuronectes limanda(L) or platessa(P) or flesus(F)	Asterias rubens Star Fish	Carcinus maenas Shore Crab	Ostrea edulis Oysters
Esso Solvent FG155		10-33						
Banner DG01		10-15						
Banner DG02		8-12						
Banner DG03		10-15						
Banner DG04		15-20						
Basol AD6		10-15						
Cuprinol 106		4-8						
Penetone X		20-30						
Polycomplex A		100-200	33-100		33-100 (L)			
Craine OSR		500-750						
Corexit 7664		7500-10000	3300-10000		1000-3300 (L)			
Mobilsol		10-33						
Houghtosolve		10-33						
Raynap Sol B		3.3-10						
Foilzoil		330-1000	33-100					
BP 1100		> 3300	1000-3300	1000-3300				
Ridzlik		330-1000						
Dermol	148	156	148					
Corexit 8666		> 3300						
New Dispersol OS (Dispersol SD)		3300-10000		100-330				
New BP 1100 A		> 3300						
New BP 1100 B		> 3300						
Finasol ESK		100-330						
Finasol SC		33-100						
Hoe SC 1708		330-1000						
Snowdrift SC 98		330-1000						
Neptune Marine Cleaner		33-100						
Finasol OSR		3300						
BP 1100 A		3300-10000						
Sefoil		1000-3300		1000-3300				

D Cost-Effectiveness

1 Cost

The cost of dispersants ranges from \$2.00 - \$5.00 per gallon. Using manufacturers' recommended doses, which are usually 1 gallon of dispersant to 10 gallons of oil, the cost of chemicals for dispersing a relatively small 500 barrel spill would be about \$10,000.

Based on EPA's actual field experience, which has indicated that frequently the necessary dosage is 1 to 1 or 1 to 2, the cost might run as high as \$100,000 for this same size spill. Of course, the amount of chemical required is going to depend heavily on the type and age of oil to be treated, type of dispersant used, and the temperature of the water.

2 Effectiveness

Equally as important as toxicity, is the effectiveness of a dispersant.

Evaluation of the effectiveness of dispersants during accidental spill incidents is difficult. Lack of adequate methods for measuring the amount of oil on water and the rate of natural dispersion make precise evaluation impossible. Their effectiveness during the Torrey Canyon is still being debated. Subsequent incidents which are claimed to have demonstrated their effectiveness have been at remote locations and without impartial, qualified observers. Application methods of dispersants and subsequent agitation, which are critical for effective performance, have not always been optimal.

As an initial step in trying to solve this problem EPA developed a standard test for measuring emulsion efficiency (4). At the present time, four private labs are "testing the test" to determine its applicability using a variety of oils and dispersants. Figure 2, which shows the results of testing done at the Edison Water Quality Laboratory adequately demonstrates the degree of variability which will occurr when using different dispersants on the same type of oil and when using the same dispersant on different types of oil.

E EPA Policy

The present policy regarding the use of dispersants is shown on the following pages.

TABLE 2.
APPARENT COMPOSITION OF TEST CHEMICALS

Product	Surfactant Ionic Nature[1]	Surfactant Basic Composition[2]	Solvent[3]
A	Nonionic	Ethylene oxide condensate of alkyphenol	Aromatic, aliphatic hydrocarbon, boiling point range similar to that of number 2 fuel oil
B	Nonionic	Ethylene oxide condensate of alkylphenol	Water, glycol
C	Nonionic	Polyhydric alcohol ester of fatty acid	Water, short-chained alcohol
D	Nonionic	Alkanolamide	Water
E	Anionic	Alkyl aryl sulfonate	Aromatic, aliphatic hydrocarbon, boiling point range similar to that of number 2 fuel oil

[1] According to Weatherburn test.[19]

[2] By infrared spectral analysis of dried (105°C) residue: test was not definitive, but results consistent with stated, presumed composition.

[3] By distillation and infrared spectral analysis.

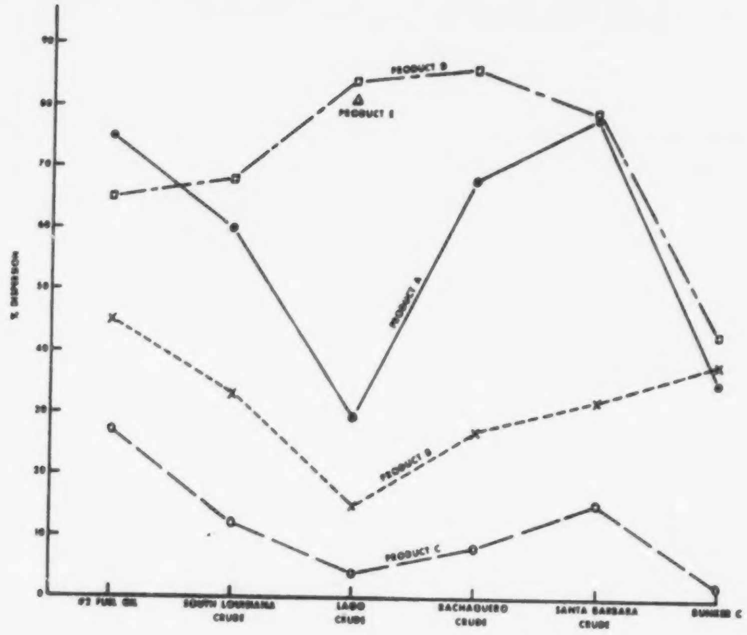

FIGURE 2. OIL DISPERSANT EFFECTIVENESS

ANNEX X

2000 SCHEDULE OF CHEMICALS TO REMOVE OIL AND HAZARDOUS SUBSTANCES DISCHARGES

2001 General

2001.1 This Schedule shall apply to the waters of the United States and adjoining shorelines, and the waters of the contiguous zone.

2001.2 This Schedule applies to the use of any chemicals as hereinafter defined that may be used to remove oil and remove or neutralize hazardous substances discharges.

2001.3 This Schedule advocates development and utilization of mechanical and other control methods that will result in removal of oil and hazardous substances discharges from the environment with subsequent proper disposal.

2001.4 It is the intent of this Schedule that no harmful quantities of any substances be applied to the waters to remove or neutralize the effects of oil or hazardous substances discharges.

2001.5 Relationship of the Environmental Protection Agency to other Federal and State agencies in implementing this Schedule: in those States with more stringent laws, regulations or written policies regulating chemical use, such State laws, regulations or written policies shall govern.

2001.6 It has been determined that because of the overriding need for prompt initiation of discharge removal actions, no formal permit as provided for by section 402 of the Act, shall be required before application of chemicals to mitigate the effects of a discharge. The provisions of Section 1510.21(g) of this Plan shall apply.

2002 Definitions. Substances applied to oil or floating hazardous substances discharges are defined as follows:

2002.1 Collecting agents - are those substances that concentrate, congeal, entrap, fix, gell, or make the pollutant mass more rigid or viscous in order to facilitate removal from the water's surface.

2002.2 Sinking agents - are those substances that can physically sink the pollutant below the water's surface.

2002.3 Chemical agents - are those elements, compounds or mixtures that disperse, dissolve, emulsify, neutralize, precipitate, oxidize or reduce the pollutant on the water's surface or in the water column.

2003 Collecting agents - are considered to be generally acceptable providing that these materials do not in themselves or in combination with the pollutant increase the environmental hazard.

2003 Collecting Agents - may be used only when authorized by the On-Scene Coordinator on a case by case basis. The OSC can authorize that use only after considering the effects on the performance of the collecting agent of ambient temperatures, wind, wave action, debris and other foreign material in the water, type of oil, and availability of removal operations to remove the collected oil. Technical guidance on application techniques and dosage rates will be provided by EPA.

2004 Sinking Agents - shall not be used for oil and hazardous substances pollution control.

2005 Authorities controlling use of chemical agents.

2005.1 Major and medium discharges. Chemical Agents may be used in any place, at any time, and in quantities designated by the On-Scene Coordinator, when their use will:

2005.1-1 In the judgement of the OSC, prevent or substantially reduce hazard to human life or limb or substantially reduce explosion or fire hazard to property;

2005.1-2 In the judgement of EPA, in consultation with appropriate State agencies, prevent or reduce substantial hazard to a major segment of the populations(s) of vulnerable species of waterfowl; and,

2005.1-3 In the judgement of EPA, in consultation with appropriate State agencies, result in the least overall environmental damage, or interference with designated water uses.

2005.2 Minor discharge. The provisions of section 2005.1-1 shall apply. The use of chemical agents in any other situation shall be subject to this Schedule except in States where State laws, regulations, or written policies that govern the prohibition, use, quantity, or type of chemical are in effect. In such States, the State laws, regulations or written policies shall be followed during the removal operation.

2006 Restrictions on use of chemical agents for pollution control purposes. Except as noted in 2005.1 above, chemical agents shall not be applied to the waters to remove discharges:

2006.1 of distillate fuel oils;

2006.2 of less than 200 barrels of oil;

2006.3 from any beach;

2006.4 in waters less than 100 feet deep;

2006.5 in waters, identified in regional plans, containing major populations, or breeding or passage areas of species of fish or marine life which may be damaged or rendered commercially less martketable by exposure to chemical agents or disperse pollutants.

2006.6 in waters where winds and/or currents are of such velocity and direction that chemically treated mixtures would likely, in the judgement of EPA, be carried to shore areas within 24 hours; or

2006.7 on any waters where such use may affect surface drinking water supplies.

2007 Chemical agent use. Chemical agents may be used for removal of oil discharges in accordance with this Schedule if other control methods are judged to be inadequate or infeasible, and if:

2007.1 Technical information on the physical, chemical, and toxicity characteristics of the chemical agents has been submitted in duplicate to the DOHM, EPA, Washington, D.C., 20460, at least 60 days prior to the chemical agent's use. The submission shall include the information required in sections 2007.3 and 2007.4 as well as dispersant effectiveness and toxicity data obtained in accordance with the EPA standard analytical procedures specified in "Standard Dispersant Effectiveness and Toxicity Test" (EPA R2-73-201, May 1973).

2007.2 Information furnished in accordance with section 2007.1 shall be maintained on file by EPA to provide technical guidance to pre-designated OSC's on the acceptable circumstances of use and dosage rates for the chemical agents(s).

2007.3 Chemical agent containers shall be labeled with the following information:

2007.3-1 Name, brand or trademark, if any, under which the chemical agent is sold;

2007.3-2 Name and address of the manufacturer, importer or vendor;

2007.3-3 Flash point;

2007.3-4 Freezing or pour point;

2007.3-5 Viscosity;

2007.3-6 Special handling, storage or worker safety precautions;

2007.3-7 Recommend application procedure(s), concentration(s), and conditions for use depending upon water salinity, water temperature, and types and ages of the pollutants; and

2007.3-8 Date of production and shelf life.

2007.4 Information to be supplied to EPA:

2007.4-1 Chemical agent name and percentage of each component;

2007.4-2 Specific gravity;

2007.4-3 Solubility in fresh or salt waters at 15°C;

2007.4-4 Concentrations of potentially hazardous trace materials, including, but not necesarily being limited to arsenic, chromium, copper, lead, mercury, nickel or zinc; or chlorinated hydrocarbons; and

2007.4-5 Description of the analytical methods employed and results obtained in determining the chemical and biological characteristics of the chemical agent. This information shall be described in an official report from a recognized laboratory.

2007.5 For purposes or research, development and demonstration, EPA may authorize use of chemicals in specified amounts and locations under controlled conditions irrespective of the provisions of this Schedule. Guidelines have been published (FEDERAL REGISTER, Vol. 36, No. 75, April 17, 1971) for this purpose.

Note: In addition to those agents defined and described in section 2002 above, the following materals which are not a part of this Schedule, with cautions on their use, should be considered:

1. Biological agents - are microbiological cultures or enzymes or nutrient additives that are deliberately introduced into an oil or hazardous substance spill for the specific purpose of encouraging or speeding biodegradations to mitigate the effects of a spill. These agents may be used only when such use is the most desirable technique for removing oils or hazardous substances and only after obtaining approval from the appropriate state and local public health and water pollution control officials. Biological agents may be used only when a listing of organisms or other ingredients contained in the agent is provided to EPA in sufficient time for review before its use.

2. Burning agents - are those materials which, through physical or chemical means, improve the combustibility of the materials to which they are applied. Burning agents may be used and are acceptable so long as they do not in themselves, or in combination with the material to which they are applied, increase the pollution hazard and their use is approved by appropriate Federal, State and local fire prevention officials.

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5. Federal Register, Vol. 38, Number 155, August 13, 1973.

This outline was prepared by Richard T. Dewling, Director, R & D, Edison Water Quality Laboratory, OWP, EPA, Edison, NJ 08817.

TREATMENT OF OIL SPILLS - SINKING AGENTS

I DEFINITION - USE POLICY

Sinking agents are oil-attracting and water repelling sorbent materials designed to sink oil slicks out of sight rather than agglomerating oil on the water surface. The use of oil sinkants would seem advantageous in deeper waters outside heavy fishing zones, such as off the continental shelf and where adverse effects upon biological bottom life may be held at a minimum.(8) Existing EPA policy on sinking agents restricts their use to waters exceeding 100 meters in depth.

Oily discharges into inland rivers and coastal waters do not remain floating forever since much of the oil will be naturally absorbed onto clay, silt and other particulate matter normally suspended in the water, thus causing eventual sinking of the oil. Sinking by natural means, for example, is believed to be one of the primary causes for the disappearance of oil slicks in the New York Harbor complex.

II TYPES

Various types of natural materials and commercial products are presently available which are claimed to be effective in sinking oil slicks.(1,3) Typical agents include sand, brick dust, fly ash, china clay, volcanic ash, coal dust, cement, stucco, slaked lime, spent tannery lime, carbonized-siliconized-waxed sands, crushed stone, vermiculite, kaolin, fuller's earth, and calcium carbonate, including the "Oyma" type chalk used during the TORREY CANYON.

Sinking agents are believed most efficiently employed on thick, heavy and weathered oil slicks in contrast to relatively light and fresh oils. These agents are granular or fine particulate solids with a specific gravity generally between 2.4 and 3.0. These agents must be evenly distributed over the surface of a a slick and suppled with proper mixing, agitation and time interaction. The particle-coated and agglomerated mass eventually becomes heavier than water and sinks to the bottom.

III PERFORMANCE

The major problem in sinking oils is that the bonding of the agent with the oil must be nearly permanent. Experiments in both the laboratory and field show that many agents will release entrapped and sunken oils back to the water environment. Increasing the application rate two or three times over prescribed amounts has served to minimize this release.

Studies conducted by various investigators (4, 5, 6, 7, 9, 10, 12) indicated that:

A Sulfurized oils may show greater sinking abilities than desulfurized oils because of higher potentials for hydrogen bonding.

B When sands are used for sinking it may be expected that the oily mass will be stable under water when the sands are closely packed and the interstices are filled with oil giving an oil content around 40 per cent and a bulk density about 1.7. However, when the sands are loosely packed, the mass will become internally mobile so that oil drops will separate and escape to the water until equilibrium is reestablished.

C With carbonized sand, it was indicated that up to three pounds of sand would be required to sink one pound of oil. Large-scale applications of amine-coated sands envision spraying the sand in a slurry form from a large vessel or hopper dredge.

In ports and harbors it has been mentioned that turbulence or agitation of the water body caused by storms or passing vessels may tend to release oily masses previously sunk. For siliconized sand, it has also been suggested that one per cent bone flour or an inexpensive fertilizer may be added to promote bacterial growths and accelerated decomposition of the sunken mass.(2,4) Table 1 summarizes the types, application rates and relative costs of various sinking agents.

IV FIELD EXPERIENCE

The most prominent large-scale application of sinking agents was that undertaken by the French to sink large masses of TORREY CANYON oils in the Bay of Biscay. Some 3,000 tons of calcium carbonate (blackboard chalk from the Champagne area of France) coated with about one per cent sodium stearate, was used to treat and sink about 20,000 tons of floating oils, although this amount was never precisely defined. The powdery chalk was sprayed or sprinkled over the thick, highly viscous and weathered oil patches and thereafter the water surface was mixed by vessels criss-crossing the area. The oil-chalk mixture reportedly sank in about 60-70 fathoms of water. The area of sinking was known to partially cover scamp fishing grounds and thus there was fear of bottom inundation and oil resurfacing. Numerous observations, since this incident, however, have reported no adverse effects upon fisheries and bottom life, and there have been no sightings of resurfacing oils upon the water or adjoining shorelines. Nevertheless, it was concluded that lack of knowledge on the precise fate of the oil shows need for further trials before this method may be recommended in other situations. (11, 13, 14, 15, 16, 17)

Opinion still remains divided on the use of oil sinkants as to their efficiency, cost, application, and possible adverse effects. With sinking agents, the same problems are encountered in the application and distribution as was indicated in the lecture on floating sorbents. However, with sinking agents, operational logistics become increasingly more difficult because of the much larger amounts of material required for treatment

Although damaging effects have been ascribed to toxicity and smothering of bottom life by sunken oils, the sinking approach serves to localize oil pollution, to prevent its spread over the water surface, and theoretically submerge and anchor the oil near the source of pollution. Considering that the bottom of harbors and bays near many industrial ports are grossly polluted and nonproductive, emergency sinking of oils in these areas may not increase damage to fisheries. Dilution by flowing waters in certain areas may also be sufficient to adequately minimize toxicity to nearby shellfish grounds. The other important point of view is that sinking agents, even if used in harbor areas because of fire or explosion danger, can at best be of temporary benefit. The resurfacing oils, although less objectionable due to weathering, may require pick up. Furthermore, sinking may greatly extend the period over which aquatic fauna and flora are affected. (1, 2, 8, 12)

V R & D PROGRESS

Dutch Shell Laboratories, Holland, (11) was one of the first groups to really evaluate sinking agents on a field scale basis Their studies, still underway, involve using sand treated with an amine. One very important finding from their investigations was that there was a correlation between clay content and performance as measured by the percentage of oil sunk. The lower the clay content the more efficient the sinking agent. The Warren Spring Laboratory, United Kingdom, (6) impressed by the results of these studies, conducted similar field investigations during 1969. Conclusions reached by the Warren Spring Laboratory were as follows:

A The sinking was not as effective as first hoped and it would appear that the thickness of the oil film is an important factor. Nevertheless, between 50 and 70 per cent of the oil put on the sea was sunk.

B The skin divers reported that the oil sank to the bottom in small particles which were only slightly more dense than the sea. Consequently, the tidal current along the sea bed was sufficient to carry the oil over the ripples of sand on the bottom.

C Trawling was carried out and although no actual lumps of oil were collected, sufficient oil was rubbed onto the netting of the trawl to foul both the catch and the fishermen when they were pulling it back into the vessel.

D The oil which remained afloat was particularly difficult to dispose of using either more sand slurry or the normal solvent emulsifier mixture agitated by water hoses. Further investigations on this particular phenomenon are being carried out both in England and in Holland.

In the United States, the Army Corps of Engineers, under contract to U. S. Coast Guard, is evaluating various types of sinking agents--treated and untreated--as well as investigating the possibility of using their hopper dredges, normally used for dredging harbors, to handle and apply the sinking agents. Results of these studies should be available in 1971.

TABLE I - **OIL SINKING AGENTS, APPLICATION RATES AND OTHER OPERATIONAL DATA**[A]

Type Material	Application Ratios (Weight Sinking Agent: Weight Oil Treated)	Comments
Silica, untreated	....	Released oil easily after sinking
Carbonized sand	1:1 to 3:1	Higher proportion of sinking agent considered most appropriate; $27/ton carbonized sand (1948); specific gravity particles = 2.7
Sands, amine-coated	3.2 to 2:1	Large-scale application costs estimated $5 – $10 per ton of oil treated
Sands, 0.5% silicone coated	....	More effective on heavier oils
Fly ash, untreated	....	Released oil easily after sinking
Fly ash, 0.5% silicone coated	2:1 ratio or higher	Permanent oil sinking reported; more effective on lighter oils.
Spent tannery lime	....	Good oil retention properties after sinking
Kaolin clay	....	Released oil easily after sinking
Bentonite, montmorillinite clay, treated and untreated	....	....
Calcium carbonate	....	Released oil easily after sinking
Fuller's earth	1:1 to 9:1	1:1 to 3:1 for sulfurized oil; 3:1 to 9:1 for desulfurized oil.
Calcium carbonate – Champagne chalk treated with 1% sodium stearate	Approx. 1:1	Used off the coast of France during the Torrey Canyon. $60 – $80/ton sinking agent. Specific gravity particles – 2.7
Synthetic silicate	....	High efficiency in absorbing fuel and crude oils; some difficulty in sinking the mass.
Synthetic plus filler material	4:3 or higher	Estimated $120/ton sinking agent

[A] Bibliography (2, 3, 4, 9, 10, 12, 13, 14)

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TREATMENT OF OIL SPILLS - BURNING AGENTS

I INTRODUCTION

Burning of oil on water or land by special methods and materials seems to offer an attractive and perhaps inexpensive means of eliminating large amounts, providing of course, the many significant hazards are also recognized. Freshly spilled oils and crudes containing volatile components are relatively ignitible. If a thick layer of oil on water is present, the oil will sustain burning until the volatiles and a portion of the heavier fractions are combusted. Conversely, with fresh oil spills within a harbor or confined area, a significant fire danger exists when the level of hydrocarbon vapors is within the range of flammability, (e. g. gasoline, aviation fuels, or light crude oils). (1, 2)

Wood, debris or other material caught within an oil slick can serve as a wick to start or sustain an oil fire. The cooling of a layer of oil by the water body beneath will greatly deter burning. However, the wick will withdraw the oil and insulate the burning oils from the cooling action of the water, and at the same time provide a renewal and vaporization surface for combustion.

II EXPERIENCE ON WATER

A General

Experience by certain investigators has indicated that floating oils on the sea with thicknesses less than 3 millimeters (0.12 inches) will not burn. It is also reported that layers of kerosene, gas oil, lubricating oil and fuel oil on water will not burn at all without a wick. In one instance, attempts were made to ignite fresh Iranian crude oil five minutes after a spill without success. Once an oil spillage has spread, the material quickly loses its volatile components and ignition is extremely difficult. Weathered oils are consequently reported to present almost no fire hazard. (1, 2, 3)

B EPA Lab Experiments

In experiments carried out at the Edison Laboratory, a heavy fuel oil and a lightweight crude oil were placed atop a layer of water contained in metal tanks with 24-square-feet of exposed surface area. Attempts were made to combust the oils using different burning agents. It was concluded from these experiments that the light crude, freshly applied in a floating thickness of 2.5 millimeters (0.1 inches), required external support with burning agents and an ignition source to burn near completion.

When the No. 6 fuel was used for testing, one of the agents used would not sustain burning at a thickness of 1/2 to 2/3 inches. Another agent generously applied over the surface ot the No. 6 fuel caused sporadic burning and the minimum required oil thickness to sustain burning was 1/3 to 1/2 inches. It is important to note that a thickness of 1/3 to 1/2 inches is equivalent to an oil slick of 7 million gallons/sq. mile. It was evident after this burning that appreciable oil was still remaining. A third agent used performed well with the No. 6 fuel at a thickness of 1/10 to 1/4 inches. The manufacturer producing this material, however, suggests that in order to have complete burning of all the oil, the oil layer must be completely covered with the material with no broken patches. Required amounts of this material (very low bulk density) may be as high as one pound for each 12-15 square-feet of oil slick. (3, 4)

C EPA Field Tests

Field scale oil slick burning experiments, with and without special agents have been undertaken in 1970 by both the U.S. Navy and the Edison Water Quality Laboratory. Preliminary data from these experiments indicate the following:

1 Burning of free floating or uncontained oil slicks is extremely difficult unless the thickness of oil is 2mm or greater.

2 Adequate automated seeding methods for both the powder and nodule-type burning agents are lacking. Spreading of the burning agent on the oil slick had to be accomplished by hand. This conclusion was also reached by the Navy, which conducted burning experiments in May 1970.

3 Contained South Louisiana crude oil was successfully burned - 80% to 90% reduction-without the application of

burning agents and/or "priming" fuels. Bunker C could not be ignited under these same conditions.

4 Bunker C was successfully burned - 80% to 90% reduction - When the slick was seeded with burning agents and an appropriate priming fuel. It was discovered that South Louisiana crude oil performed better as a priming agent than did gasoline or lighter fluid.

5 Use of magnesium type flares and gasoline torches to ignite the burning-agent-treated slick proved unsuccessful. Success was achieved, however, using a blow torch once we learned how to manipulate the torch in such a manner that the torch gas pressure did not push aside the oil and seed material so as to expose the water surface.

D U. K. Experience

Burning agents were considered when the TORREY CANYON was in the final stages of destruction off the British coast in March of 1967. As a last resort, the British Government attempted simultaneous and complete burning of the 15,000-20,000 tons of oil remaining in the badly broken tanker by aerial bombing, incendiaries, and catalyst-oxidizing devices. The major objective was to penetrate and lay open the decks by "explosive surgery," exposing the oil in the storage compartments to large amounts of oxygen required for burning. High-explosive, 1,000 pound bombs filled with aluminum particles, thousands of gallons of aviation fuel, napalm bombs, rockets, and sodium chlorate devices served to produce a massive fire, if not a sustained fire. The British concluded that no appreciable amounts of oil escaped burning, but if any did, it was lost to the open sea. (5,6)

E Use Considerations

Controlling the burning oil mass and ensuing air pollution problems would appear to preclude intentional burning except where the oil mass is distant from the coastline, offshore facilities, vessels, etc. The safety and welfare of all parties however remote from the burning site are of utmost importance. The possible loss of additional oil, and the loss of a drilling platform or vessel at the source of the spill must be recognized. Because of potential merits in controlled burning, further research is desired on new methods, techniques and procedures both in the laboratory and in the field, together with additional guidelines for burning.

III EXPERIENCE ON LAND

J. Wardly Smith, Ministry of the Environment, United Kingdom, has conducted a series of research experiments involving the burning of oil on beaches. The conclusions reached by these studies were:

A The type of heavy oil normally contaminating beaches and the foreshore is very difficult to burn by ordinary means and combustion ceases when the source of heat is removed.

B The addition of solid oxidants aids the combustion of part of the deposit, but a sticky, tarry residue is left with medium heat and a residue of dry, black carbon with prolonged intense heat. About 30 per cent by weight of oxidant has to be employed to achieve this and when the deposit occurs on sand, shingle or pebbles the amount of heat necessary to raise the whole to ignition temperature is so great that, in practice, the cost of removal would probably be excessive.

C The application of an oil-absorbent, combustible material, such as sawdust impregnated with an oxidant, resulted in a much steadier burning rate and an increased removal of the deposit. The additive, however, burns away before the higher-boiling, tarry fractions begin to burn.

D Although some improvement was obtained by adding materials which function as a wick, the same limitation regarding the amount of heat to be supplied still prevailed.

E A major disadvantage of burning as a method for the removal of oil deposits on beaches, especially when dealing with the large semi-solid lumps, is that, when heat is applied, the oil becomes mobile and penetrates deeper into the beach, thus increasing the contaminated area if it becomes exposed at a later date.

F On the basis of these small-scale experiments it was considered that, for all practical purposes, burning beach oil deposits would be less efficient and more costly than mechanical or manual removal, and that further investigation would be unprofitable.

IV COMMERCIAL BURNING AGENTS

Commercial burning agents are available for promoting combustion of an oil slick. However, in most cases it is apparent these agents are designed for a relatively thick oil layer which is sufficiently contained. These agents are intended to serve one or more functions such as providing increased surface area exposed to burning; addition of catalysts, oxidizers and low-boiling volatile components; absorbence and entrapment of the oil; or creating a wicking mechanism via surface diffusion and capillary action by the material added.

To the best of our knowledge, burning agents are available from only four sources:

A Eduard Michels GmbH, 43 Essen, Postfach 1189, Ruttenscheider Str 1.: "Kontax", the commercial name for this agent, ignites spontaneously when it comes in contact with water. In 1969, the Dutch conducted field experiments which included burning of oil on beaches, and in open waters. Results of this investigation indicated that the quantity of "agent" required was dependent upon wind, condition of sea and continuity and thickness of oil.

Dutch engineers also reported that a method should be developed to jettison, hurl or catapult the "agent" from a vessel in such a way that there is not the slightest risk of having the "agent" come in contact with rainwater or spray. Dropping from an airplane is worth considering provided special packaging requirements are met.

B Pittsburgh Corning, One Gateway Center, Pittsburgh, Pa.: Known as "Seabeads", these cellulated glass nodules are available in sizes from 1/8" to 1/4" in diameter. By capillary action, the nodules become coated with oil. Depending upon the type and age of the spilled oil, combustion is accomplished by using an incendiary device alone, or in combination with a "primer fluid" such as gasoline. After burning, SeaBeads still remain, therefore, they must be collected or left to break up by abrasion. During the "Arrow" incident in 1970, this burning agent was used, with varying degrees of success, on small patches of spilled oil.

C Guardian Chemical Corporation, Long Island City, NY 11101: Pyraxon, a powder material, is a catalyst containing small amounts of oxidizing materials. Pyraxon liquid is used as the priming agent or starter fluid, with the powder being sprayed, blown or dropped onto the oil, in and around the flame.

D Cabot Corporation, 125 High Street, Boston, Ma.: Cab-O-Sil ST-2-0 promotes combustion by acting as a wicking agent. Produced from fumed silica, this powdery-like material, is surface treated to render it hydrophobic. It may be applied directly to the slick or by spraying in a stream of water. Combustion is best accomplished by using an incendiary device in conjunction with a "primer fluid". Reportedly, this product was used successfully for handling a 2,000 gallon spill at Heard Pond, Wayland, Ma.

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TREATMENT OF OIL SPILLS - GELLING AGENTS

I INTRODUCTION

Gelling agents are applied over the surface or periphery of a floating oil slick and are intended to absorb, congeal, entrap, fix, or make the oil mass more rigid or viscous so as to facilitate subsequent physical or mechanical pick up. The gelling concept is also undergoing extensive study for stabilizing petroleum cargoes aboard a stranded or heavily-damaged tanker at sea subject to mass spillage.

II TYPES AND COST

Possible gel agents include molten wax or soap solutions, lanolin, liquid solutions of natural fatty acids, soaps of the alkaline metals, treated colloidal silicas, the amine-isocyanates, and the polymer systems. One manufacturer indicates a cost of $3 per gallon of gel agent, a use ratio of about 1:1, and the ability to mix the recovered gel mass with fuel oils serving as replacement bunker fuel. This gel agent is applied to the surface of the water by a high-pressure spray system to provide sufficient agitation and mixing of the gel-oil mass.

III R & D FINDINGS

Preliminary research on the gelling of tanker cargoes tends to show that a 3-10 per cent gel agent will be required at a materials cost of 13-40 cents per gallon of tanker crude oil gelled. However, total operational costs, and the ability to salvage and reuse the gelled cargoes, are not fully known at this time.

The gelling approach for treating oils on water, although promising, must provide greater attention to application and distribution, lower materials and operational costs, and suitable means of picking up the amorphous oily masses. Bunker C, heavy crude oils, and some gel agents by themselves may clog intakes, pumps and suction lines. The major difficulty is the ability to harvest the congealed mixtures isnce gelled oils cannot be easily collected by mechanical or manual means. Necessary improvements are needed in the gelling approach in line with a total operational cleanup system. (1, 2, 3, 4)

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This outline was prepared by R. T. Dewling, Director, Research & Development, Office of Water Programs, Edison Water Quality Laboratory, Edison, NJ 08817

SURFACE COLLECTING AGENTS

I "SURFACE COLLECTING AGENT"- WHAT IS IT?

A surface collecting agent is a pure liquid, or a solution containing a component which has a spreading force on water that is higher than that of oil on water. When applied to water around the periphery of a thin oil film it will spread on the surface, forcing the oil to compress. Compression of the oil film will reduce its are drastically, and increase thickness, up to some equilibrium thickness which depends upon the oil's characteristics. The reduced area and the thickness of the compressed oil film is such that it becomes feasible to remove it from the water.

The amount of compression depends upon the gravity of the oil, the relative spreading forces of the oil and agent, and the initial thickness of the oil film.

Compression will be limited to that which results in an equilibrium thickness:

$$t^2 = -\frac{2\,(F_o - F_1)\,\rho_w}{G_c\,\rho_o\,(\rho_w - \rho_o)}$$

where t = oil film thickness, cm

F_1 = spreading force of collecting agent, dyne/cm

F_o = spreading force of collecting oil, dyne/cm

ρ_o = density of oil film, gm/cm^3

ρ_w = density of water, gm/cm^3

G_c = gravitational constant, 980 cm/sec^2

and, further, where

$$F = \sigma_w - (\sigma_o - \sigma_{ow})$$

In this last equation, is the interfacial tension, and the subscripts w, o, ow, refer to the water/air, the oil (or agent)/air, and the oil (or agent)/water interfaces respectively.

As an example, consider a film 1 micron (1×10^{-4} cm) thick, in the rainbow color range. Suppose this is formed by an oil having a density of 0.9 gm/cm^3 and a spreading force of 35 dyne/cm, and it is collected by an agent having a 40 dyne/cm spreading force. The calculated equilibrium thickness is 0.113 cm, representing a 1,130:1 increase in thickness, and a 1,130:1 reduction in area.

In a field test during an actual spill cleanup, a rainbow film of Navy Special Fuel Oil, originally 30,000 ft^2 in area was compressed into several thick globules, 3 - 10 inches in diameter, suitable for pickup by sorbent or skimmer. Application rate as about one gallon per linear mile.

II COLLECTING AGENTS AS DISTINGUISHED FROM DISPERSANTS

Dispersing agents are in the same chemical family as surface collecting agents; they both are, or contain surface active agents. On initial application, the former will also have a compression effect similar to that of collecting agents when applied the same way. At present, it appears that a practical distinction can be made on the basis of water solubility. The rationale is that by virtue of lower solubility, the surface collecting agent will:

A Remain effective for a longer period of time (persistence) because the film remains intact longer.

B For any application rate, will have a lower toxicity and BOD effect on the underlying water column.

The data in Table I, obtained at the Edison R&D Laboratory illustrates this difference. These data show only the solubility difference between agents offered commercially; they do not indicate in any way relative performance either as dispersant or collecting agent. Appendix A contains the test method.

TABLE I

PERCENT NOT DISSOLVED IN SOLUBILITY TEST

Product	%Not Dissolved
Classed as Dispersant	
Magnus	20
BP 1100	40
Corexit 7664	0
Corexit 8666	170*
Polycomplex A 11	0
Met Aquaclean	0
Classed as Collecting Agents	
Shell Herder	80
W.G. Smith	100

* Undissolved phase was apparently an emulsion

III BIOLOGICAL CONSIDERATIONS

A surface collecting agent spreads rapidly over the water surface. Initial spreading rates are at least 30 cm/sec, falling with time to about 5 cm/sec. During the first six minutes, the average rate is about 10 cm/sec. If the initial application covers a strip of water 1 meter wide, then at the end of six minutes the covered strip will have spread to about 35 meters wide.

At an application rate of two gallons per linear mile, the initial coverage would be about 5,000 mg/m^2. After spreading to 35 meters, the coverage would be about 140 mg/m^2.

If in the above case the agent were to dissolve completely in the top 1 meter layer of the underlying water, immediately after application, the concentration resulting from the 5,000 mg/m^2 layer would be 5 ppm. If similar complete solution took place, suddenly, after a six-minute spreading time, the resulting concentration would be 0.14 ppm.

The above concentrations represent upper limits. Owing to the relative insolubility of the agent, and the speed of initial spreading, actual concentrations of 1 ppm or less can be expected at the 2 gal/mile rate.

Preliminary data on toxicity to marine life indicate that a concentration of 1 ppm is at least one order of magnitude below the TL_{50} of a typical agent.

IV OPERATIONAL ASPECTS OF APPLYING SURFACE COLLECTING AGENTS

An effective agent can push oil against about a quarter-knot current. At higher currents, the system of agent-plus-compressed oil will be carried with the current.

An agent can push oil against the drag exerted by wind of a few knots - about 2 - 5 knots. At higher wind speeds, the agent-oil system will be driven down wind.

In a field test by Edison R&D, at a local oil spill, application from helicopter appeared more effective than application from a boat, for two reasons:

A A given area can be ringed-in much faster by the aircraft.

B The high angle of view from the aircraft made it easier to see the outer boundary of the thin film. From the low angle of the boat, it was hard to see the film-water boundary to establish where to apply the agent.

V RECOMMENDATIONS FOR USE

Surface collecting agents can be useful in oil spill control and clean up, bearing in mind the particular circumstances of wind, current, film thickness and other aspects of each individual problem. If in the judgment of the On-Scene Coordinator the situation warrants application of such agents, our interim and conservative recommendation is that the surface collecting agent be applied at a rate not to exceed two gallons per linear mile per six hour period, with no more than three applications in twenty-four hours.

This system of application has several benefits:

A The low application rate of two gallons per linear mile will not, in our opinion, cause adverse affects on the marine environment.

B By reapplying every six hours on an as needed basis, the necessary persistance of the particular surface collecting agent can be maintained.

C By allowing three applications, six hours apart, the On-Scene Coordinator has the opportunity to limit the amount of surface collecting agent to the minimum required to achieve clean up of the spilled oil.

This outline was prepared by Bernard Hornstein, Chemical Engineer, Oil Spills Research Section, R&D, Edison, NJ 08817.

INTERIM TEST TO DISTINGUISH BETWEEN SURFACE COLLECTING AGENTS AND OTHER OIL SPILL CLEANUP CHEMICALS

In order to distinguish between surface collecting agents and other chemical materials, this interim test procedure was developed. The development work consisted of evaluating five test procedures using six oil dispersants and six surface collecting agents. This test gives clear, distinguishing results, requires no expensive equipment, and can be performed in the field by the On-Scene Coordinator. Additional work will be performed to improve and modify this test as required and to verify its reproducibility.

Anyone using this test procedure should keep in mind that it is not an efficiency test. This test is to be used only to distinguish between oil collecting agents and oil dispersants.

SCOPE

1 Procedure to be used to determine the solubility in water under standard conditions of oil spill control chemicals.

METHOD SUMMARY

2 Five (5) milliliters of the chemical under test are intimately mixed with ninety-five (95) milliliters of distilled water, allowed to stand undisturbed for one hour, and then the volume of the upper phase is determined to the nearest 1 milliliter.

APPARATUS

3 a Mixing cylinder, 100 milliliter volume with 1 milliliter subdivisions and fitted with teflon stoppers.

b Pipettes: 0.1 milliliter with 0.01 milliliter subdivisions, and 5.0 milliliter volumetric.

c Timers

PROCEDURE

4 Add 95 milliliters of distilled water at 72°F ± 5°F to a 100 milliliter milliliter mixing cylinder. To the surface of the water in the mixing cylinder, add 5.0 milliliters of the chemical under test. Insert the teflon stopper and invert the cylinder 5 times in 10 seconds. Set upright for one (1) hour ar 72°F ± 5°F and then measure the chemical layer at the surface of the water. The major portions of the chemical added (75%+) should be at the water surface as a separate and easily distinguished layer.

TREATMENT OF OIL SPILLS

Sorbents

I INTRODUCTION

A Sorbents are oil spill scavengers or cleanup agents which adsorb and/or absorb oil. Based on origin, sorbents may be divided into three general classes:

1 Natural products

2 Modified or chemically-treated natural products

3 Synthetic or man-made products

B Sorbents may be further classified as to their physical characteristics:

1 Powdery products

2 Granular products

3 Fibrous materials

4 Pre-formed foam slabs or sheets

II TYPES OF SORBENT PRODUCTS

Types of floating sorbent materials presently available are:[1]

A Natural Origin: Types derived from vegetative sources comprise straw, hay, seaweed, kelp, ground bark, sawdust, reclaimed fibers from paper processing, and peat moss. Types derived from mineral sources may include the various clays, including montmorillinite, kaolin, fuller's earth, diatamaceous earth, etc.; vermicultite and the other micas, many forms of silicates, perlite, pumice, and asbestos. Sorbents of animal origin include chrome shavings from leather processing, wool wastes, feathers, and textile wastes.

B Modified Natural Products: These materials comprise most of the sorbent types mentioned above but are chemically-treated to produce a more desirable result. Some of the modified types are expanded perlite, charcoal, stearate-coated talc, asbestos treated with surfactant, and sawdust and vermiculite coated with silicones.

C Synthetic Products: These sorbents include a vast array broadly categorized as plastics and rubber, but more specifically as the ethylenes, styrenes, resins, polymers and co-polymers.

III SORBENT CHARACTERISTICS

Desirable Sorbent Characteristics

A Oleophilic - has greater attraction for oil than water.

B Hydrophobic - repels or rejects water.

C Adsorbtive - oil will adhere to the surface of the material.

D Absorbtive - oil is assimilated into the material.

E High oil capacity - the ratio of oil picked up to material applied (lb/lb) should be at least 5:1 but preferably 10:1 or greater.

F Retentive - leaking of oil from material should be minimal after harvesting.

G Low costs - on a non-reusable product. High initial costs are acceptable for reusable products.

H Products should float under all conditions.

Presently, none of the existing products have all of these desirable qualities.

IV OPERATIONAL ADVANTAGES AND DISADVANTAGES

A Advantages

1 Aids in removing oil from water surface and alleviates or precludes undesirable after effects.

2 Minimizes and decreases spread of oil.

3 Generally, inexpensive and available in large quantities.

4 Non-toxic.

5 May increase both performance of booms and skimming techniques.

6 Minimizes shore pollution when bleached.

B Disadvantages

1 No effective workable system at present.

2 High labor costs associated with acquisition, transportation, stockpiling, deployment, distribution on and working into an oil slick, retrieval and ultimate disposal.

3 Manual retrieval only practical under calm conditions.

4 Some products interfere with other forms of physical removal by clogging skimming and suction devices.

5 Pollutional problems on disposal.

6 Some sorbent products ultimately sink.

a As their true density is greater than water, certain mineral products sink when air entrained in capillaries is replaced by oil and/or water or when products are wetted by water.

b Some natural vegetative products such as straw, sawdust or waste pulp fibers become waterlogged upon prolonged exposure in water and may sink.

V SORBENT USES

Sorbents may be used for many reasons.

A To agglomerate oil from a massive spill to minimize spread and potential damage. The above could be applicable to spills on large open bodies of water where other control procedures are ineffective and in other areas where presently available control procedures would be effective but are not readily available.

B To "polish" a slick remaining after other control procedures such as booming and skimming have removed most of the oil.

C To sorb free oil from contaminated surfaces to facilitate cleanup procedures.

D To deploy sorbents onto open waters and clean beaches in anticipation of the arrival of an uncontrolled slick.

E Used in conjunction with either fixed or towed booms.

VI SORBENT EFFECTIVENESS

To define sorbent effectiveness certain basic questions relating to the environmental use of sorbents under actual spill conditions must be considered.

A Why were sorbents used?

B What procedures will be used to harvest the oil-sorbent mass?

In each of the situations listed in Section V, the effectiveness must be evaluated differently because criteria for evaluating effectiveness must be related to the original objective for each different use.

For instance, the cost/application ratio (i.e. product costs/unit of oil sorbed) may be of primary importance in selecting a product for agglomerating a massive spill but would be of a lesser degree of importance for "polishing" action or for alleviating or minimizing potential damage.

VII SORBTION PROCESSES

A The accumulation of oil by sorbent products is a complex phenomenon dependent upon several physical processes. For example, when straw is used the different processes most probably occur as follows:

1 Adsorbtion of oil to the straw surface.

2 Absorbtion of oil into the interstitial fibers and filtration into the hollow stem.

3 When saturation is reached additional oil is picked up by oil to oil cohesion.

B Products have different adsorbtive and absorbtive capacities. For example, for free flowing oils:

1 A highly pulverized mineral product manifests primarily adsorbtion. The pickup capacity is related to the surface area available.

2 A polymeric foam product manifests primarily absorbtion because of its high internal porosity.

3 The extraneous oil pickup of all products is related to the viscosity of the oil to be sorbed. The higher the viscosity, the greater the oil to oil cohesion and adhesion.

VIII USING SORBENTS EFFECTIVELY

On unconfined oil slicks

A Products should be uniformly applied to the slick. Most unconfined oil slicks thin out very readily. Therefore, in order not to waste product, a thin uniform layer is preferred.

B The effectiveness of most products is increased by ultimately mixing the product into the oil slick. This can be accomplished:

1 By churning up the mass by running boats through at high speed after broadcasting of products.

2 By towing netting stretched between boats through the mass at slow speed.

3 By existing environmental energy such as wind, wave and current action.

4 If the above is not feasible, a time period of at least 3-6 hours should be allowed for the oil and product to mix. Most spills occur in tidal areas, and as such, the change of tide produce a minimum mixing energy. Additionally, the weight of most sorbent products will be sufficient to work the product into the oil if sufficient time is allowed.

5 A harvesting procedure utilizing netting or booms which encircles a given area and concentrates the oil/ sorbent mass by decreasing the area is also effective.

IX OIL CAPACITY AND COSTS OF SORBENTS

A Presently, there are no standard tests for evaluating the effectiveness of sorbents. However, small scale laboratory testing of many products have been completed which at least give a measure of the relative oil capacity of many available products.

B Table I summarizes the results of bench scale testing of the oil sorbing capacity of selected products. The data was summarized from Edison Water Quality Laboratory tests, the oil pollution literature and manufacturers' brochures.

C Table I reflects product costs varying from $20 to $20,000 per ton which breaks down to costs of approximately $0.02 to $1.00 per gallon of oil sorbed. These costs are product costs only, based on the reported oil capacity of the products. They do not reflect the equipment and labor costs associated with their use in the environment.

D Compared with other oil spill cleanup techniques such as booming, skimming, dispersing and sinking, cleanup with sorbents is reportedly the most costly procedure. The costs vary from $0.50 to $5.00 per gallon of oil picked up, depending on the size of the spill and the equipment utilized. In the absence of an effective system for utilizing sorbents under actual spill conditions, the high cost are a reflection primarily of the labor costs of the multi-step process.

X LARGE SCALE SORBENT TESTS

E.A. Milz(2) of Shell Pipeline Corporation, Houston, Texas, reported the performance of 15 floating sorbents tested on a relatively large scale.

A Summary of test data is presented in Table II.

B Conclusions from tests.

1 Tests showed that pound for pound polyurethane and urea formaldehyde foams are the best oil sorbents. On a weight basis these materials removed about 10 times more oil than other sorbents tested.

2 For long contact times the quantity of oil sorbed is primarily a function of oil viscosity and density.

3 In most cases sorbents lose oil after pickup by drainage and evaporation. About 80% of oil initially absorbed will be retained after draining for 24 hours.

a One exception to the above is Kraton rubber which dissolves oil into the body of the material and completely retains it. To facilitate sorbtion, samples were granulated to a particle size of 4 mm. Kraton rubber may also be foamed which should improve sorbtion.

4 Power mulching machines can effectively spread up to nine tons of straw or hay per hour with immediate mixing with oil. In contrast, when hay was simply dumped overboard, it remained in large dry clumps for over half an hour even in 4-5 foot waves.

5 Power mulchers are satisfactory for shredding and spreading polyurethane foams.

6 When sorbents are used with booms the same problems are encountered as by containment of oil alone by booms. Wave action will cause spill-over and currents above 1 fps will cause undersweep.

7 Nets are more effective than booms for containing relatively small quantities of stringy material such as hay, bark and shredded foam. With 1-inch mesh nets, velocities of 2-3 fps are possible for small quantities of material without product loss. For large quantities of material, velocities of 1-2 fps are possible without failure (Figure 1).

8 All collection or harvesting processes for oiled sorbents on open water involve screening processes. Therefore, the selection of mesh size for harvesting devices is critical and is related to the sorbent particle size.

XI POTENTIAL OF SORBENTS

A Because of the inherent limitations or regulatory restrictions for such techniques as booming, skimming, sinking, dispersing, burning or gelling, the advantages of sorbent systems for cleaning up oil spills show great promise.

B Reusable high-oil capacity sorbent products used in conjunction with self-contained mechanized systems will be developed which will have the following desirable features:

1 Recovery of oil which decreases problem of disposal. The recovered oil can be taken to a separator and incorporated into refinery feeds rather than buried.

2 Products will be reusable. Certain poly-foam products have an initially high-cost which decreases geometrically for each subsequent re-use. Such products may be used dozens of times

and potentially hundreds of times by reinforcement of product with plastic netting.

3 On open waters under inclement conditions there is no expediency for harvesting. The products may be beached and subsequently the oil and product recovered on the beach or gathered later under calm conditions from the water surface.

C Costs will decrease as manual labor is replaced by mechanical equipment incorporated into continuous self-contained systems.

D Presently the EPA, U.S. Coast Guard and the API are evaluating proposed sorbent systems submitted for research funding.

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TABLE I

COSTS OF SORBENTS(1)

(Product costs per 1,000 gallon spill. Does not include labor and equipment costs)

Type Material	Pick Up Ratio Weight Oil Pick Up Weight Absorbent	Unit Cost Absorbent $ (Ton Absorbent)	$ Cost of Absorbent for Cleanup of 1,000 Gals. Oil Spill[B]
Ground pine bark, undried	0.9	6	27
Ground pine bark, dried	1.3	15	47
Ground pine bark	3	---	---
Sawdust, dried	1.2	15	50
Industrial sawdust	---	56	---
Reclaimed paper fibers, dried, surface treated	1.7	30	75
Fibrous, sawdust and other	3	---	---
Porous peat moss	1.0	---	---
Ground corncobs	5	30	21
Straw	3-5	30	27
Chrome leather shavings	10	---	---
Asbestos, treated	4	500	440
Fibrous, perlite, and other	5	416	290
Perlite, treated	2.5	230	320
Talcs, treated	2	70-120	120-210
Vermiculite, dried	2	---	---
Fuller's earth	---	25	---
Polyester plastic shavings	3.5-5.5	100	80
Nylon-polypropylene rayon	6-15	---	---
Resin type	12	3,100	900
Polyurethane foam(1)*	70	20,000	1,000
Polyurethane foam(2)	15	4,500	1,050
Polyurethane foam(3)	70	---	---
Polyurethane foam(4)	40	2,260	195
Polyurethane foam(5)	80	1,200	55

*Numbers refer to different types.

TABLE II

LARGE SCALE SORBENT TESTS(2)

Test Conditions: Sorbent applied to oil slick confined to 20' x 20' area, no mixing

Sorbent Material	Quantity Used (lbs.)	Test Oil Thickness (in.)	Test Oil Quantity (lbs.)	Test Oil Viscosity (cs.)	Test Time (hrs.)	Oil Removed (lbs.)	Oil to Sorbent Ratio
Kraton 1101	25	1/4	700	4	24	28	1.1
Kraton 1107	25	1/4	700	4	24	ca. 30	1.2
Urea Formaldehyde 2" x 24" x 60"	1.6	1/4	700	4	24	41	26
Polyurethane(1)	20	1/4	556	6	2	560	28
Polyurethane(2)	20	1/4	660	6	1	100	5
Polyurethane(3)	5	1/4	300	6	5	230	46
Ekoperl	24	1/4	300	6	24	120	5
Hay(4)	49	1/4	700	6	24	210	4

1. Fine ground polyurethane (ca. 1/4" diameter). For this test there was insufficient oil present to saturate the polyurethane. There was no trace of oil left after removing the polyurethane.

2. Polyurethane in 9-feet long by 2-feet diameter bag. The bag picked up over 500 pounds of water and only 102 pounds of oil.

3. Scraps of polyurethane of 1 and 2-inch thickness in various shapes and sizes up to 1-foot by 4-feet.

4. Performance of straw and bagasse are similar to hay.

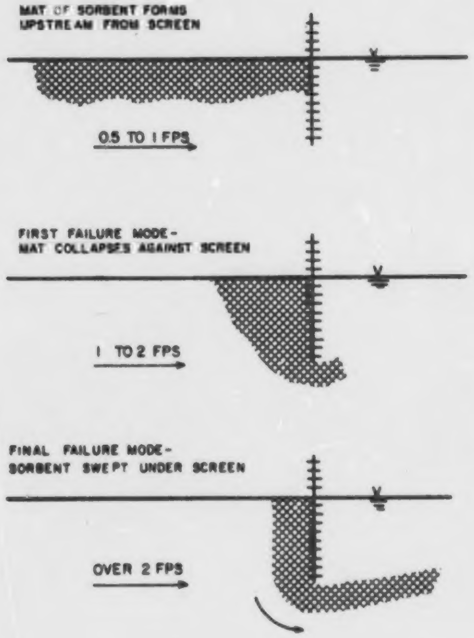
MAT OF SORBENT FORMS
UPSTREAM FROM SCREEN
0.5 TO 1 FPS
FIRST FAILURE MODE-
MAT COLLAPSES AGAINST SCREEN
1 TO 2 FPS
FINAL FAILURE MODE-
SORBENT SWEPT UNDER SCREEN
OVER 2 FPS

Fig. 1 - Sorbent Barrier Failure Modes in Current

CONTROL OF OIL SPILLS

Booms

I INTRODUCTION

In spite of everyone's best efforts at prevention oil has been, and will continue to be spilled on the water. What do you do about it once it's there? From other information presented in this training manual you know that, if ignored, it won't go away. It may move away from the area where it was deposited, but if left in or on the water, something will be adversely affected by it. If you are the party responsible for the loss, it is a violation of federal law, Section 11 (b) (3), of the Federal Water Pollution Control Act, as amended (84 Stat. 92 33 USC 1161) not to report the oil loss, and after you report it, it will be to your advantage to do something about it. If you are a pollution control official or have delegated responsibilities in this area, you also will want to do something about it. But what?

The first priority in your control program is to attempt to limit the spread of the oil mass. Experience has shown that if left to its own devices, oil spreads into thinner and thinner films and breaks apart into smaller patches covering larger areas. The greater the area covered the more difficult and costly the clean-up program becomes. As the oil mass spreads, resources such as municipal, industrial, and agricultural water supply sources; waterfowl, fish and general aquatic flora and fauna; recreational interests, both public and private, as beaches, shorefront properties and homes, marinas, pleasure boats and tourist centers; and shellfish harvesting, to name a few, may be affected. To contain an oil spill within a limited area, oil retention barriers commonly called "oil booms" have been developed. A satisfactory boom design has to overcome the many forces acting upon it.

Forces are exerted by the oil being contained, and the water in which it is immersed. The boom may be used to encircle an oil slick to prevent its spread, to encircle an oil slick and then compact it so as to decrease the area of coverage and increase film thickness to make recovery easier, or to keep the oil away from sensitive areas. It is an essential tool in any oil pollution control program and generally will be the first piece of equipment placed on scene and the last removed. Considering its importance, an understanding of the way the barrier functions, and the limitations of different designs, is essential.

II CHARACTERISTICS OF OIL ON WATER

In order to understand the forces acting on a boom being used to contain oil in the water environment, it is first necessary to understand those forces acting on the oil itself. When oil is spilled on water, it generally tends to spread outward on the water surface forming a thin continuous layer or, depending on conditions, it may tend to accumulate as a slick having some particular thickness. How it will spread depends on the surface tension of the water, the surface tension of the oil, and the interfacial tension between the oil and water. The tendency to spread is the result of two physical forces: the force of gravity and the surface tension of the water on which the oil has been spilled. The horizontal motion of the oil slick is caused by outward pressure forces in the oil which are a direct result of the gravitational force. Of the forces acting, gravity and surface tension will tend to increase the spread of an oil film while inertia and viscous forces tend to retard it. The spreading tendency will be increased by waves, wind, and tidal currents. In general the spread resulting from these random motions will be smaller than those caused by tension and gravity forces. It must also be recognized that the character of oil when spilled on water does change with time, but generally the properties which are important to spreading, namely, density, viscosity and the surface and interfacial tensions, change slowly and, therefore, can generally be predicted.

The equations which follow define only what the diameter of an oil slick would be if it remained as an integral mass after loss. The oil mass may be transported to different locations by wind, tide or current conditions, while still spreading. If the situation is such, however, that the slick is broken apart into many smaller components, these equations may only be applied to each integral component as there is no acceptable way of accurately predicting the total area which might be covered by individual oil masses other than actual field observations.

For the situation in which a quantity of oil is spilled into the aquatic environment within a short time frame (not a slow continuous discharge), the following series of equations may be used to predict the diameter of the oil slick (l in feet) after a specified time (t in seconds).

The symbols used in the following equations may be defined as follows:

l - diameter of the oil slick in ft.

t - time in minutes from entry of oil into the aquatic environment for which size is required

v - volume of oil spilled in gallons

g - gravitational constant

32 ft/sec^2

ν - kinematic viscosity of water

$10.7 \times 10^{-6} \text{ ft}^2\text{/sec}$

σ - net surface tension of oil (typical order of magnitude)

20.6×10^{-4} lbs/ft (30 dynes/cm)

ρ - difference in mass density between water and oil (typical order of magnitude

3.12 lbs/ft^3)

Situation 1

The time period within 1 hour after the spill occurs when gravity and inertia forces are important:

$$l = \left[(\Delta g)(v)(0.13)(t^2)(60)^2\right]^{1/4}$$

Substituting typical values for constants -

$$\underline{l = 11.1\,[(v)(t^2)]^{1/4}}$$

Situation 2

The time period from 1 hour to 2 hours after a minor spill, from 1 hour to 24 hours after amoderate spill, and from 1 hour to 48 hours after a major spill when gravity and viscous forces dominate:

$$l = \left[\frac{(\Delta g)(v^2)(0.13)^2 (t^{3/2})(60)^{3/2}}{\nu^{1/2}}\right]^{1/6}$$

Substituting typical values for constants -

$$\underline{l = 6.53\,[v^2\ t^{3/2}]^{1/6}}$$

Situation 3

The final phase when surface tension is balanced by viscous forces:

$$l = \left[\frac{(\sigma^2)(t^3)(60)^3}{\rho^2\ \nu}\right]^{1/4}$$

Substituting typical values for constants

$$l = 9.66\,[t^3]^{1/4}$$

Figure 1 illustrates the application of these 3 equations to the special case of a 10,000 ton oil spill. The 3 situations are clearly illustrated. It must be remembered that values calculated are only general approximations as they are based on order of magnitude estimates.

The thickness in inches (h) of the spill may be computed at any time by the equation:

$$h = \frac{v\,(0.13)}{l^2\,(12)}$$

or

$$h = \frac{v}{l^2}\,(0.011)$$

Situation 3 describes a growth pattern which is independent of the volume v of the oil spill. This is possible as the thickness of the slick is no longer of importance in considering the major forces involved.

When the oil is being discharged from a stationary source at a fairly constant rate, a modification of the above equations is required to estimate slick width ($\bar{l}$ in ft.) at a specific distance (x in ft.) from the source. These equations may be used to model discharge patterns from sunken or grounded tankers and offshore oil wells.

Additional symbols employed are:

$\bar{l}$ - width of slick in feet

$\bar{v}$ - volume flow rate in gal/sec

x - horizontal distance from stationary source in feet

μ - current in ft/sec

The situation description for the following is the same as for bulk discharge.

Situation 1

$$\bar{l} = \left[\frac{\Delta g\,\bar{v}\,(0.13)\,x^2}{\mu}\right]^{1/3}$$

Substituting typical values for constants -

$$\bar{l} = 1.61\left[\frac{\bar{v}\,x^2}{\mu}\right]^{1/3}$$

Situation 2

$$\bar{l} = \left[\frac{\Delta g\,v^{-2}\,(0.13)^2\,x^{3/2}}{\nu^{1/2}\,\mu^{7/2}}\right]^{1/4}$$

Substituting typical values for constants -

$$\bar{l} = 3.6\left[\frac{v^{-2}\,x^{3/2}}{\mu^{7/2}}\right]^{1/4}$$

Situation 3

$$\bar{l} = \left[\frac{\sigma^2\,x^3}{\rho^2\,\nu\,\mu^3}\right]^{1/4}$$

Substituting typical values for constants -

$$\bar{l} = 0.449\left[\frac{x^3}{\mu^3}\right]$$

It should be noted that in the final phases of the spill, the spreading is independent of the volume flow rate.

The force causing the oil to spread may be calculated from the following equation (see Figure 2):

$$F_o = \alpha_w - \left[(\alpha_o)(\mathrm{CoS}\,\theta_o) + (\alpha_{ow})(\mathrm{Cos}\,\theta_{ow})\right]$$

where

F_o - force causing the oil to spread in dyne/cm

α_w - surface tension of the water, (typical order of magnitude 1 dyne/cm)

α_o - surface tension of the oil (typical order of magnitude 30 dyne/cm)

α_{ow} - interfacial tension in dyne/cm

θ_o - contact angle of oil with water at water surface in degrees

θ_{ow} - contact angle of oil/water interface with water surface in degrees

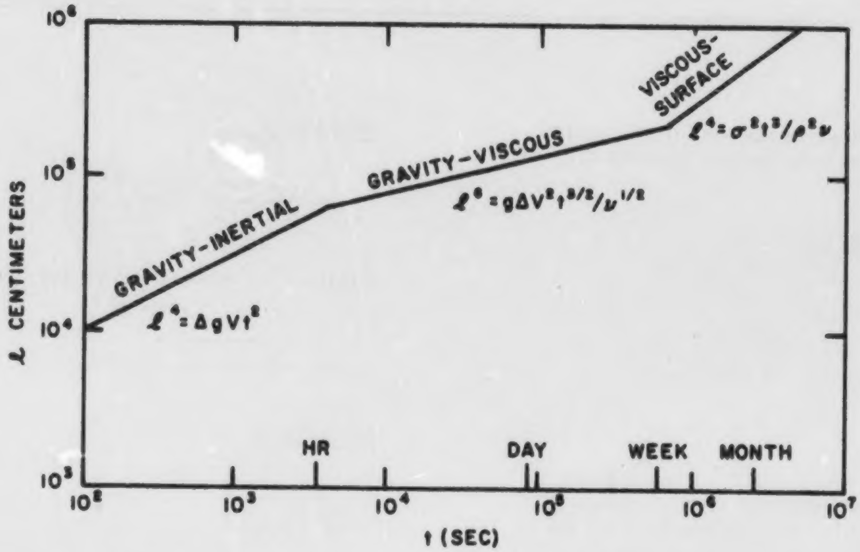

Figure 1 - THE SIZE ℓ OF AN OIL SLICK AS A FUNCTION OF TIME t FOR A 10,000 TON SPILL.

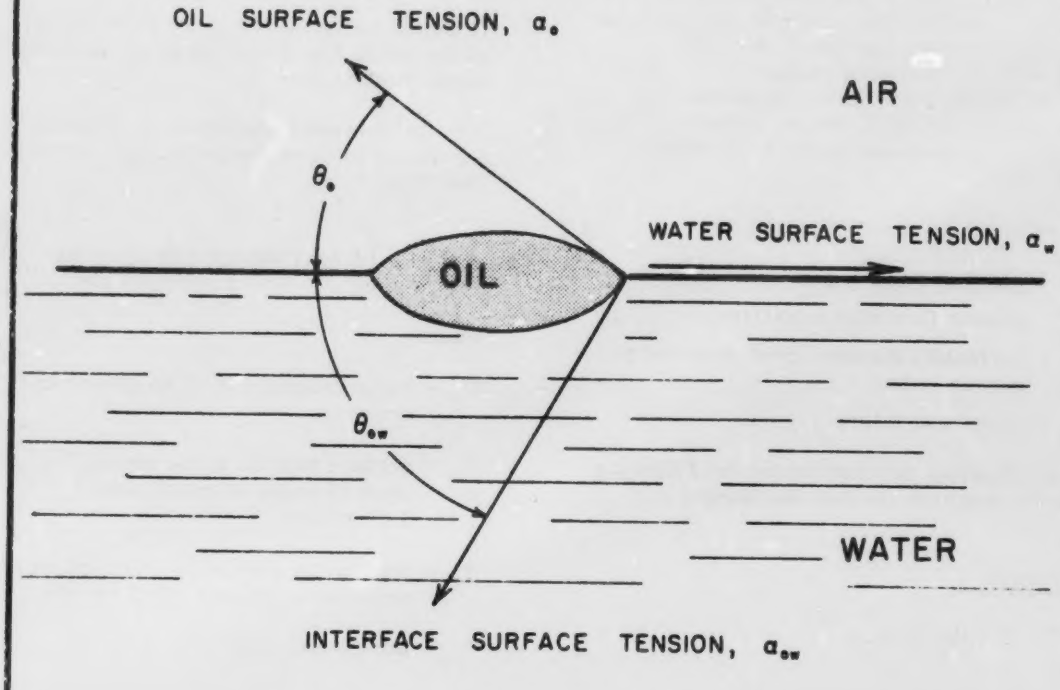
OIL SURFACE TENSION, α_o
AIR
θ_o
WATER SURFACE TENSION, α_w
OIL
θ_{ow}
WATER
INTERFACE SURFACE TENSION, α_{ow}

Figure 2 - FORCES ACTING ON AN OIL DROPLET ON WATER.

Although theoretically this force should be considered in boom design, when compared with the other forces acting to cause boom failure in the water environment, it becomes insignificant as will be seen in Section III.

Another characteristic to be considered is that a globule or droplet of oil will have a predictable "rate of rise" as it emerges from an underwater position and rises to the water surface. During the "rise" it is subject to lateral displacement by ocean currents. Large globules of oil (greater than 1 inch in diameter) rise at the rate of approximately 1 foot per second. Smaller droplets rise at about 1.5 feet per second. In placing a containment boom to capture oil either emanating from a submerged source, or falling from a substantial height, the "rate of rise" phenomena has to be considered.

For example:

A tanker has ruptured a line on deck and residual fuel oil is running out of the scuppers to the water 20 feet below. The oil is penetrating into the water to a depth of 15 feet. It will take 15 seconds to rise up to the water surface. There is an ebb tide and the current immediately off of the anchorage is 1 knot. The oil will return to the surface approximately 30 feet down current of the point of entry. A containment boom placed closer than 30 feet to the vessel would lose much of the oil being spilled.

An appreciation of the above concepts is important in understanding why a boom is necessary and how it may be used. It can provide a basis for the spill control officer to develop his own rules of thumb for predicting the physical size of the slick he is going to have to contend with. Coupled with the rule of thumb that a slick will move generally in the prevailing wind direction and at 3% of the wind velocity and taking into account the effect of tide, current and sea state, where applicable, he can begin formulating the plans for his first line of defense.

III FORCES ACTING ON A BOOM

This section will be primarily concerned with defining the reasons why a boom fails. This does not mean physical failure of the boom itself, which is a function of the structural strength of the materials out of which it is fabricated, but rather failure of the boom to contain oil while remaining physically intact. A boom is supposed to be capable of retaining oil slicks; concentrating oil slicks so as to increase thickness; acting as a device to move oil across the surface of the water from point to point; and serving as a diversionary or protection barrier to keep oil out. In almost all cases there is a regrettable tendency to overrate these capabilities rather than underrate them. With present technology, the most satisfactory way of dealing with an oil spill is to contain the oil and then physically remove it as rapidly as possible. The frequent failure of the containment system greatly complicates the physical removal effort.

When a barrier is placed in the path of an oil slick, the spread effect is interfered with and a pool of oil, generally much deeper than that which would result from an undisturbed slick, is formed.

The boom's performance is affected by wind, waves, and currents. It must be capable of conforming to the wave profile so as to maintain its freeboard and have sufficient structural strength to withstand the stresses set up by wave and wind action. Sufficient vertical stability is required to overcome the roll effect forces set up by the water current on the fin and wind on the sail to keep the boom from being flattened out on the water surface. Freeboard (sail) must be adequate to prevent oil from being carried over the top of the boom by wind action and choppy wave motions.

Although wind and wave action are important in boom design, water currents are the usual reason for boom failure. Wind is often the controlling factor in moving a slick about on the surface of the water, and wave motion often contributes to breaking up an integral slick into many smaller patches. The relative current, the resultant of that generated by the water current in the area, be it tidal or river, and the motion of the boom itself, however, will often be the controlling factor in boom failure. Boom failure is defined as a loss of its capability to retain the oil slick.

The following presents a theory, backed by experimental and field results concerning the effects of water currents on oil containment by booms. This information should assist the pollution control officer in selecting the proper depth of skirt and length of boom required in those cases where mechanical barriers appear feasible. The thought should be kept in mind that a mechanical barrier does not have to remain stationary. The relative velocity profile can be changed by allowing the barrier to drift with the oil mass. The failure mechanism can also be modified by instituting skimming action as soon as possible after the slick is boomed. Quite often, however, the amount of skimming capability available will not be adequate to prevent failure without additional action. The failure characteristics can also be modified by the use of ad/absorbents which will change the thickness profile of the oil in the boom area. An understanding of the failure mechanism provided by the following information is intended to provide a basis for deciding how the boom may best be implemented (fixed containment, drift containment, diversionary use, etc.), and how and when other materials (skimmers, ad/absorbents) might be implemented.

Experimental work has shown that an oil slick being contained by a mechanical barrier will exhibit a shape like that shown in Figure 3. Initial failure will occur when oil droplets break away from the lee side of the head wave. After a critical velocity (u_c) is exceeded, oil droplets will be entrained in the flowing water stream. Unless the droplets have sufficient time to rise through the water and rejoin the slick in Regions I or II, they will be swept under the barrier.

Region I is the critical area for defining the limits for oil breakaway. The type of configuration which the oil mass assumes in this region is similar to a gravity wave. The thickness of the oil may be found from the equation:

$$h = \frac{u^2}{2g_1 \left(\frac{\rho_w}{\rho_o} - 1\right)}$$

Where

h - oil film thickness in feet

u - water current in ft/sec

g_1 - acceleration due to gravity 32 ft/sec^2

$$\frac{\rho_w}{\rho_o} = \frac{1}{\text{specific gravity of oil}}$$

$$\#2 \text{ oil} = \frac{1}{0.8} \qquad \#6 = \frac{1}{0.99}$$

Figure 4 gives the oil thickness for a wide range of currents and oil types. The depth of the head wave will be equal to 2.4 h.

To determine the current (u_c) at which droplet formation will start, it is necessary to predict droplet size. The maximum size possible will be the control.

$$d_{max} = \pi \left[\frac{\sigma g_c}{g_1 \Delta\rho}\right]^{1/2}$$

Where

d_{max} - max. drop size in feet

σ - oil-water interfacial tension, 30 dynes/cm

g_c - 32.2 ft/sec^2

g_1 - acceleration due to gravity 32 ft/sec^2

$\Delta\rho$ - water density minus oil density in lbs/ft^3

The maximum d which can be achieved with any type of oil is 0.75 inches.

Then

$$u_c = \left[\frac{2\,\text{[illegible]}\,\sigma\, g_c}{\rho_{wd}}\right]^{1/2}$$

Where

u_c = critical velocity of which oil droplets will be torn off

ρ_w = density of water, 62.4 lbs/ft^3

For critical conditions (max. droplet size) u_c will equal 0.62 ft/sec. Below this velocity no droplets will be released from the head wave. Exceeding this velocity does not necessarily mean that oil will be lost under the barrier. It may be redeposited on the slick in Regions II or III. There will be circulation and drag phenomena working in Region II as well as the generation of waves at the oil-water interface. These will affect the location of the point of reattachment. In Region III which runs from the boom to a point = to approximately 5 times the boom skirt depth, any oil droplet entering will be swept under the boom.

The oil droplet, once released from the head wave, will be affected by the buoyant force, drag force, gravity force, and to a lesser extent, by a negative lift force. These will determine the acceleration of the droplet and the final velocity or terminal rise velocity (V_t) achieved. Typical values for this for No. 2 oil (specific gravity = 0.8) through No. 6 oil (specific gravity = 0.99) are presented in Table 2. If the length of the slick in Regions I and II is longer than

$$2h \frac{u}{V_t}$$

the droplet will reenter the oil layer. If the slick is shorter than this, the droplet will be carried under the barrier to emerge on the other side. The slick length in Regions I and II is going to depend on how the barrier is deployed and the environmental conditions existing when it is deployed. In many cases the maximum possible 1 will be obvious. In others the use of Figure 4 coupled with an understanding of the principles discussed in Section II will be of assistance.

Figures 5 and 6 provide a graphical means of predicting droplet failure for No. 2 and No. 6 oil respectively. The region below the solid horizontal line is completely safe from droplet failure. In the region above the sloping lines, droplet failure is certain. Between the sloping lines and the horizontal line, failure is uncertain. It is in this area that environmental factors, other than those allowed for, may cause problems. The dashed lines on the graph represent failure by "draining." This loss phenomenon occurs when flow conditions exist where oil can plunge under or drain past the boom with the water. Until recently this was felt to be the primary reason for boom failure. This loss can be controlled by changing skirt depth as the loss is essentially independent of the amount of oil spilled. Graphical information for determining the appropriate skirt depth is presented in Figure 7.

The volume of oil per unit breadth of boom may be calculated based on actual field conditions, either existing or predicted. This is the best approach. If this is not possible, the use of the concepts developed or referred to previously have been used to develop Figures 8 and 9. These are for an oil with a specific gravity approximately midway between No. 2 and No. 6. Figure 8 provides information which may be fit into the boom configuration associated with your particular circumstance. Figure 9 provides data for an idealized situation. Additional information may be obtained by consulting the references noted in the Bibliography, particularly No. 9 by Dr. Moye Wicks.

Air barriers are beginning to find some application as protection devices at fixed installations located in fairly quiescent waters. Generally the barrier is made from a pipe, 1 inch I.D. or less, with a series of orifices drilled through the pipe wall 1/16 inch in diameter or less. Air is supplied by either an air compressor or blower.

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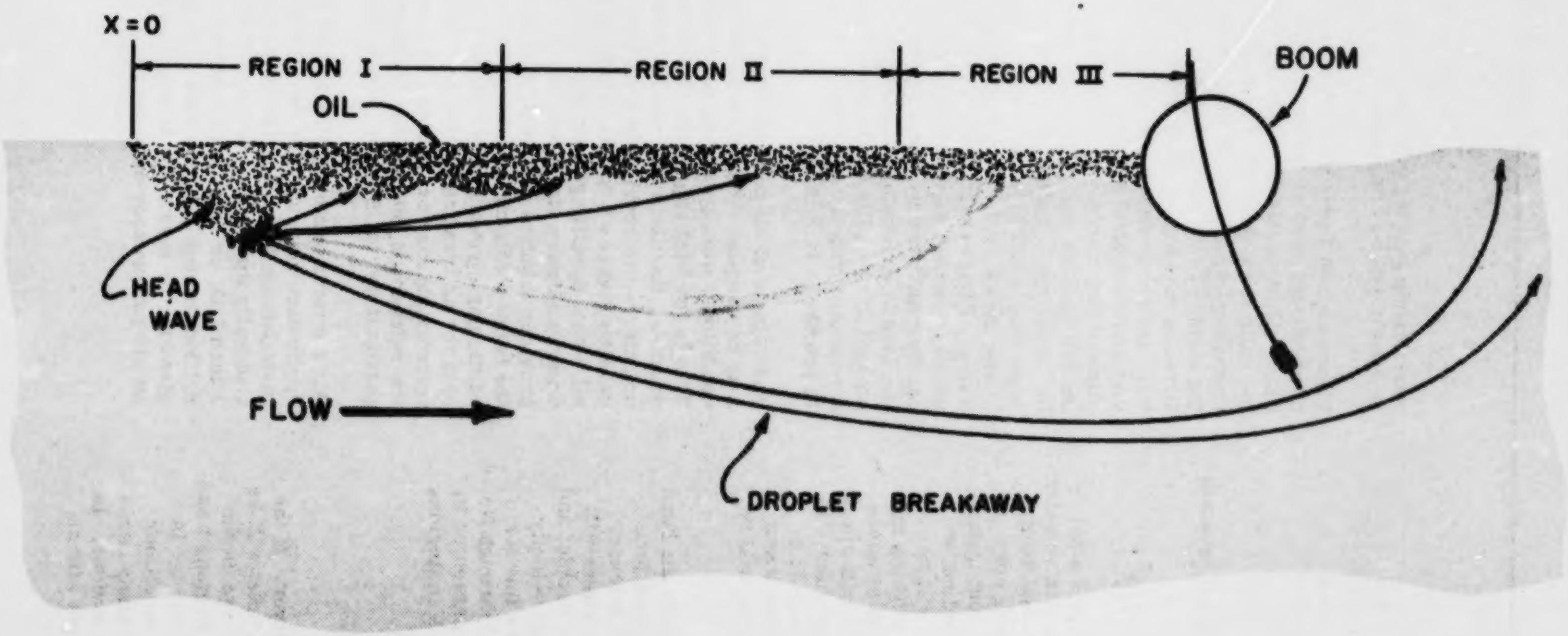
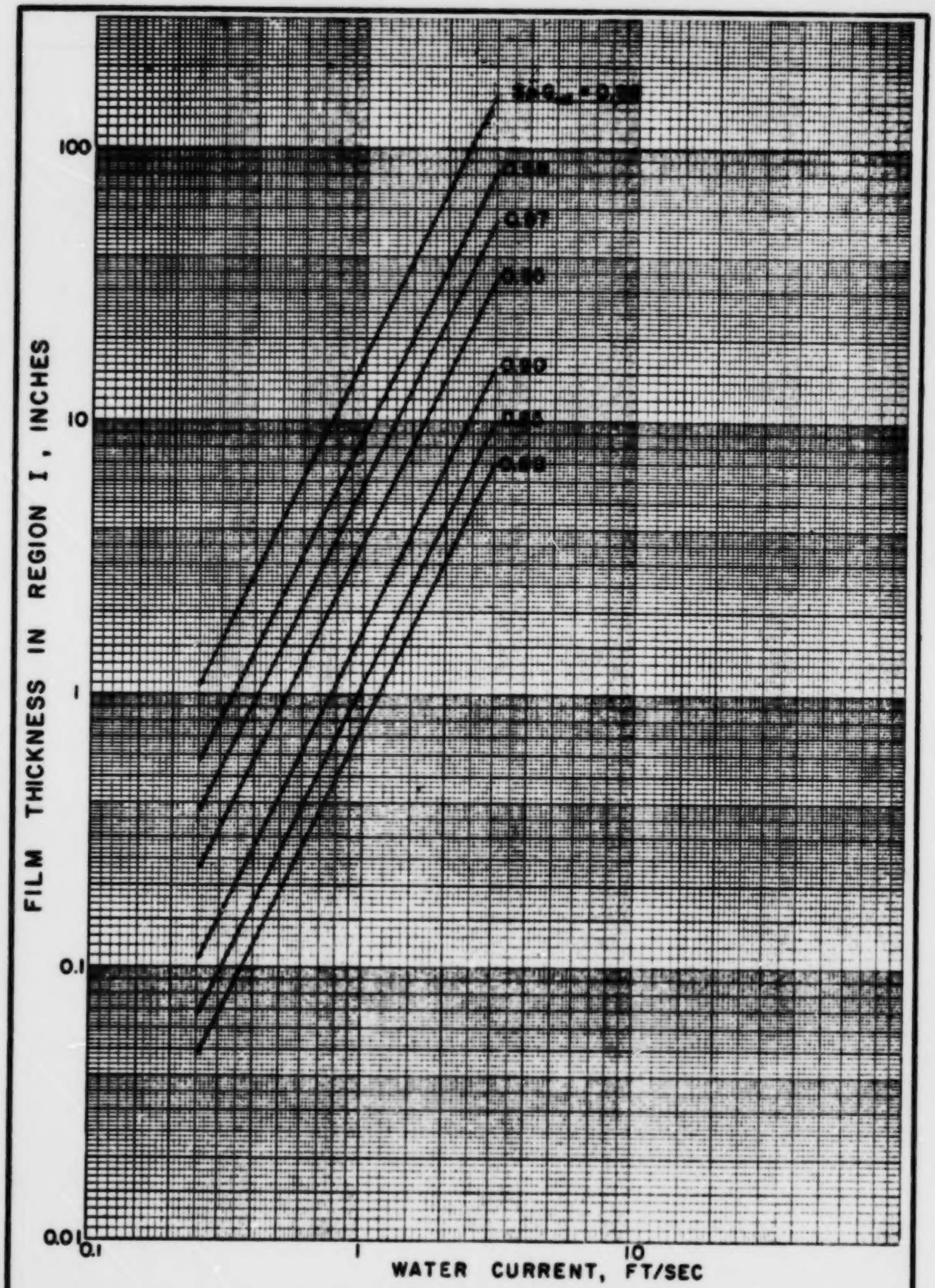

X = 0
REGION I
REGION II
REGION III
BOOM
OIL
HEAD WAVE
FLOW
DROPLET BREAKAWAY

BEHAVIOR OF AN OIL SLICK CONTAINED BEHIND A BOOM

FIGURE 3



OIL FILM THICKNESS IN REGION I

23-9

FIGURE 4

SUMMARY TABLE 1

COMMERCIAL FLOATING BOOMS

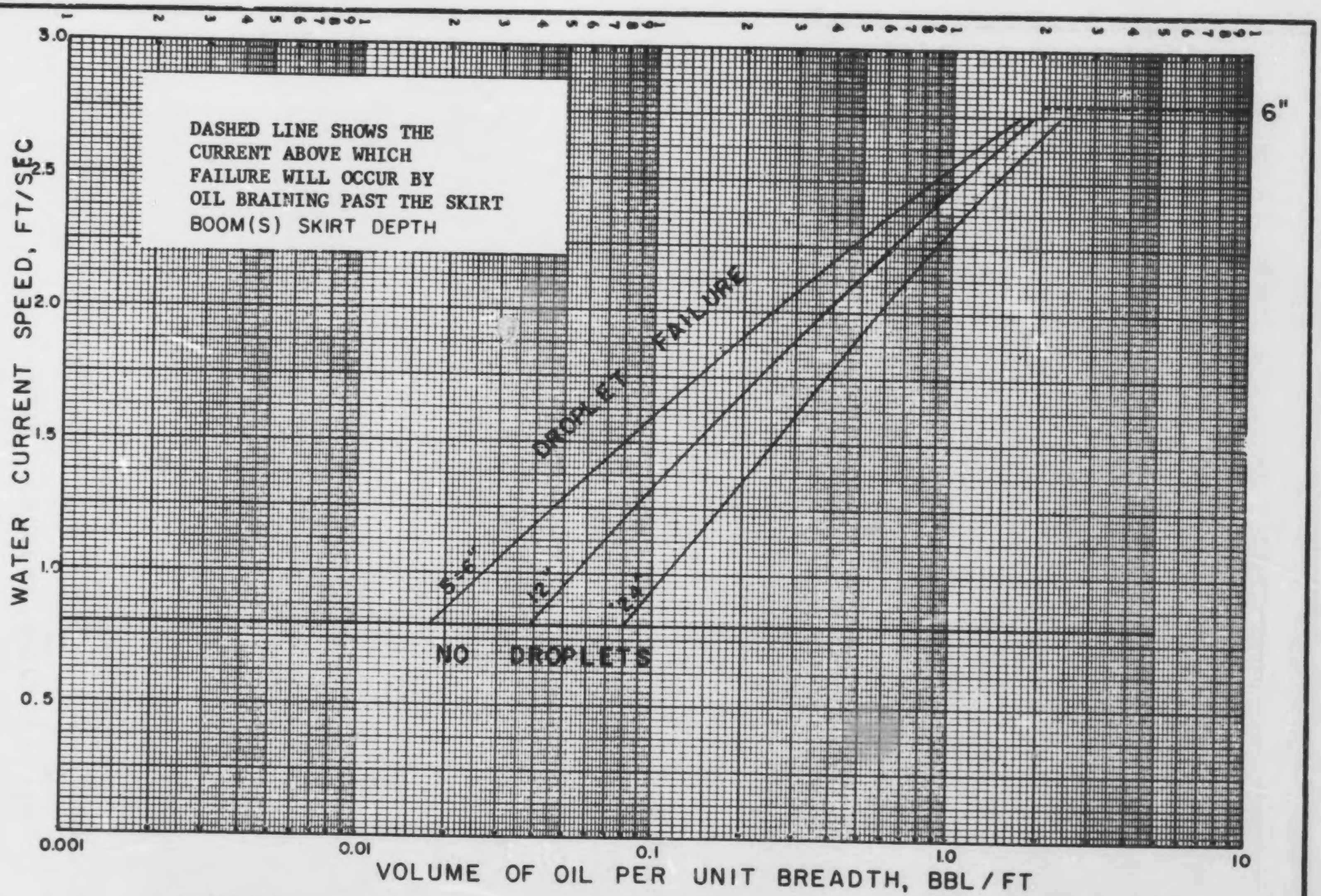
Boom	Stage of Development	Cost $/Ft.	Manufacturer
1. Abribat Boom	Under Patent	Unknown	Address Unknown France
2. Aqua Fence	Under Development	Unknown	Versatech Corporation Nesconset, Long Island New York
3. Boom Kit	In Production	Unknown	Roberts Plastics Ltd. England
4. Bristol Aircraft Company Boom	In Production	Unknown	Bristol Aircraft Company England
5. British Petroleum Company Boom	Under Patent	Unknown	British Petroleum Company Finsburg Circus London, E. C. 2, England
6. California Oil Company Boom	In Production	$2.45	California Oil Company Perth Amboy, New Jersey 07501
7. Elo-Boom	In Production	$2.20	Helly J. Hansen A/S Moss, Norway
8. English China Clay Company Boom	In Production	Unknown	English China Clay Company England

Boom	Stage of Development	Cost $/Ft.	Manufacturer
9. Flexy Oil Boom	In Production	Unknown	Smith-Anderson Company, Ltd. 3181 St. James Street West Montreal, Quebec
10. Flo-Fence	In Production	Unknown	Logan Diving & Salvage Co. 530 Goodwin Street Jacksonville, Florida 32204
11. Galvaing Floating Booms	In Production	$16.20-$22.40	Gamlen Naintre & Cie 92 Clichy, 2, Rue Huntziger, France
12. Gates Boom Hose	In Production	$50.00	Gates Rubber Company 6285 East Randolph Street Los Angeles, California 90022
13. Headrick Boom	Under Development	Expected Price $25-$35	Headrick Industries, Inc. 4900 Crown Avenue La Canada, California 91011
14. Jaton Boom	In Production	Unknown	Centri Spray Corporation 39001 Schoolcraft Road Livonia, Michigan 48150
15. Johns-Manville Spillguard Booms	In Production	$7.50-$20.00	Johns-Manville Company 22 East 40th Street New York, New York 10016
16. Kain Filtration Booms	In Production	$18.00-$23.00	Bennett International Service 302 A-5645 Topanga Canyon Boulevard Woodland Hills, California 91364

Boom	Stage of Development	Cost $/Ft.	Manufacturer
17. Marsan Inflatable Oil Barrier	In Production	$5.95 -$6.95	Marsan Corporation Box 83, Route 1 Elgin, Illinois 60120
18. MP Boom	In Production	$9.75	Metropolitan Petroleum Company, Inc. 25 Caven Point Road Jersey City, New Jersey 07305
19. Muehleisen Boom	In Production	Submitted Upon Request	Muehleisen Manufacturing Co. 1100 North Johnson Avenue El Cajon, California 92020
20. Oscarseal - Hover Platforms	Patent Pending	Submitted Upon Request	The Rath Company P.O. Box 226 La Jolla, California 92037
21. Oscarseal - Steel Boom	Patent Pending	$40 - $50	Morrison-Knudsen Company, Inc. Box 7808 Boise, Idaho 83707
22. Red Eel	In Production	$2.60	Trelleborg Rubber Company, Inc. P.O. Box 178 225 Main Street New Rochelle, New York 10802
23. Retainer Seawall	Patent Pending	$20.00 light duty $58.60 heavy duty	Environmental Pollution Systems 209 Profit Drive Victoria, Texas 77901

Boom	Stage of Development	Cost $/Ft.	Manufacturer
24. Sea Curtain	In Production	$ 2 -$ 4 light duty $10 -$15 heavy duty	Kepner Plastics Fabricators, Inc. 4221 Spencer Street Torrance, California 90503
25. Sea Fence	Experimental	Unknown	Aluminum Company of America 4-63 48th Avenue Long Island City, N.Y.11101
26. Sealdboom	In Production	$12.00	Uniroyal, Inc. 10 Eagle Street Providence, Rhode Island 02901
27. Sea Skirt	Developmental	Unknown	Core Laboratories, Inc. Box 10185 Dallas, Texas 75201
28. 6-12 Boom	In Production	$ 9.75	Worthington Corporation- Pioneer Products Division P.O. Box 211 Livingston, New Jersey 07039
29. Slickbar Oil Boom	In Production	$3.85-$ 6.80, 4" $5.25-$12.25, 6"	Neirad Industries Saugatuck Station Westport, Connecticut 06880
30. SOS Booms	In Production	$5.50-$16.50	Surface Separator Systems 103 Mellor Avenue Baltimore, Maryland 21228

Boom	Stage of Development	Cost $/Ft.	Manufacturer
31. Transatlantic Plastics Boom	Unknown	Unknown	Transatlantic Plastics Ltd. England
32. T-T Boom	In Production	$6.77-$8.08	East Coast Service, Inc. 343 Washington Street Braintree, Massachusetts 02184
33. Warne Booms	In Production	$15.00-$36.00	Surface Separator Systems 103 Mellor Avenue Baltimore, Maryland 21228
34. Water Pollution Controls Boom	Patent Pending	Unknown	Water Pollution Controls, Inc. 2035 Lemoine Avenue Fort Lee, New Jersey 07024

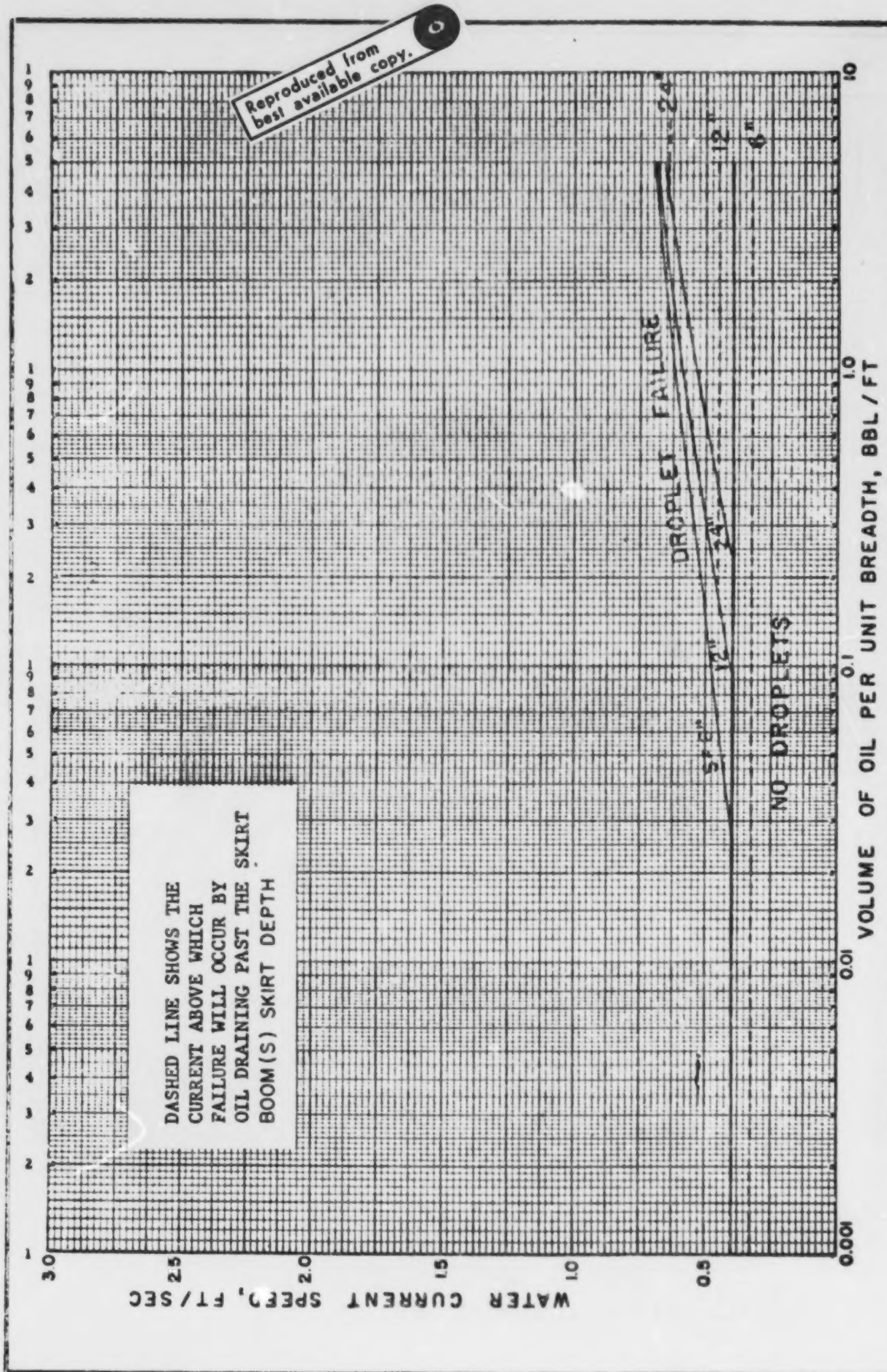


DASHED LINE SHOWS THE
CURRENT ABOVE WHICH
FAILURE WILL OCCUR BY
OIL BRAINING PAST THE SKIRT
BOOM(S) SKIRT DEPTH

FAILURE DIAGRAM FOR OIL WITH SP. GR. = 0.8, σ = 40 DYNES/CM.

FIGURE 5

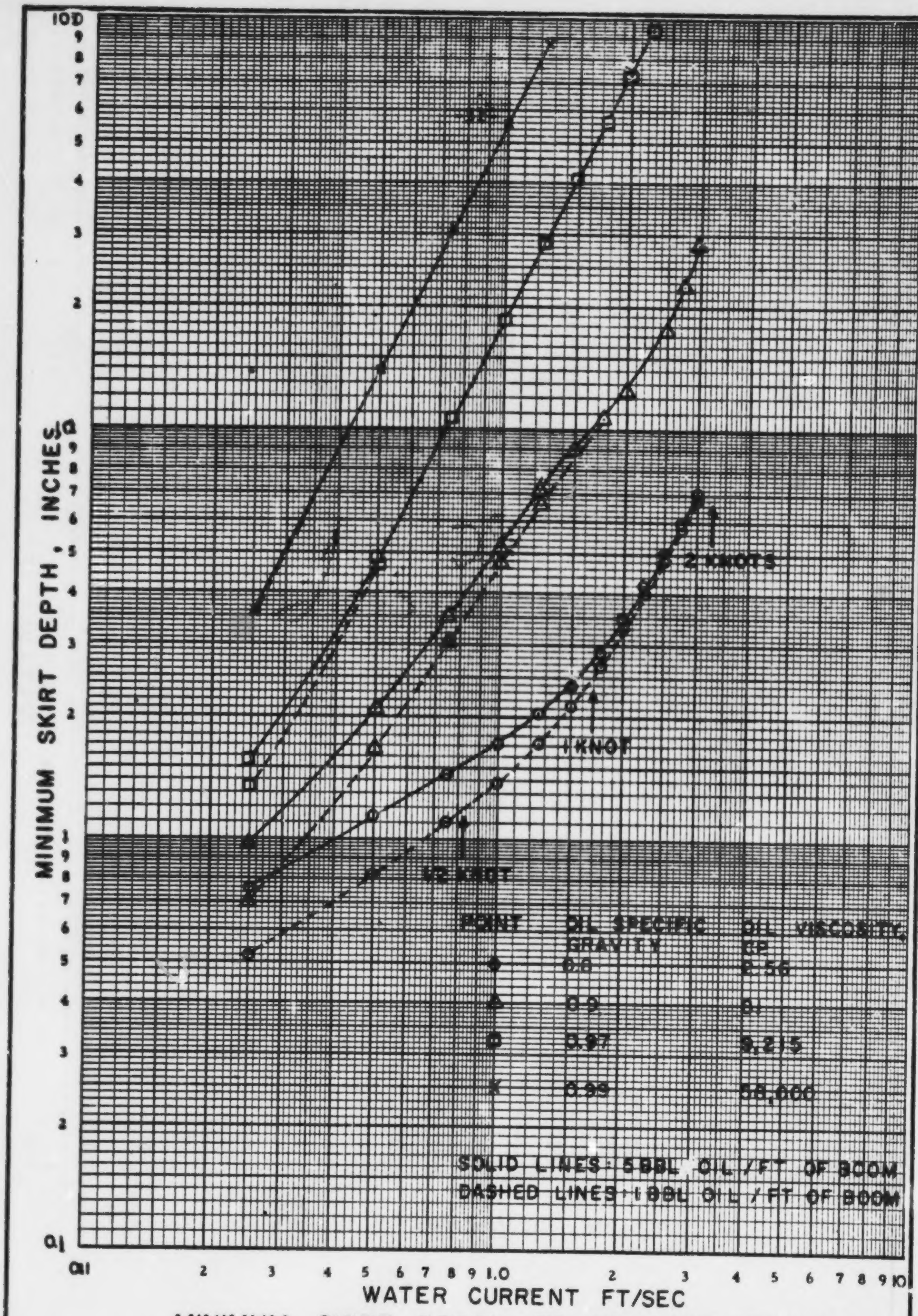
Reproduced from best available copy.



DASHED LINE SHOWS THE CURRENT ABOVE WHICH FAILURE WILL OCCUR BY OIL DRAINING PAST THE SKIRT BOOM(S) SKIRT DEPTH

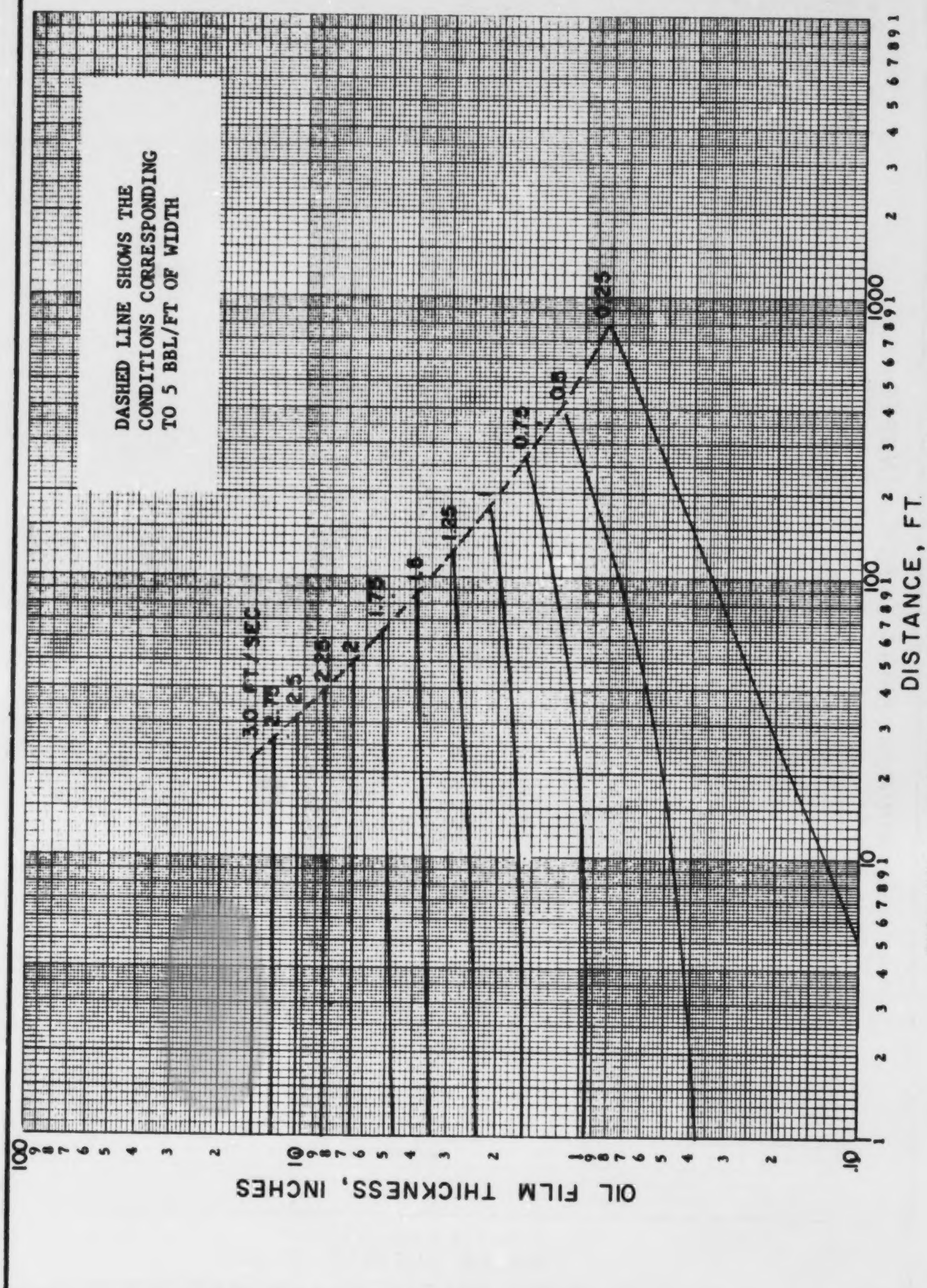
FAILURE DIAGRAM FOR OIL WITH SP. GR. =0.99, σ =40 DYNES/CM.

FIGURE 6



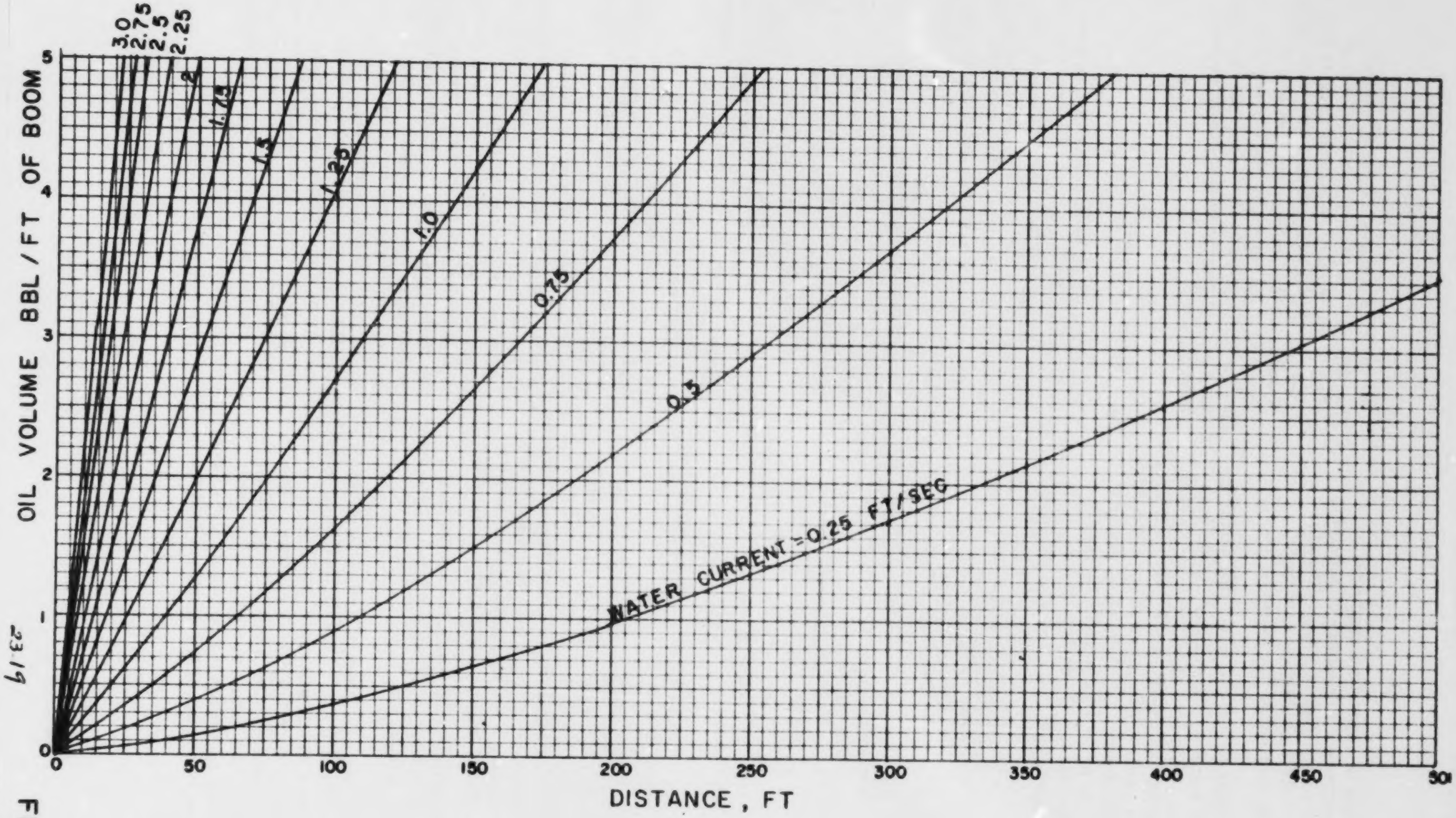
MINIMUM SKIRT DEPTH TO PREVENT DRAINING

FIGURE 7



Oil film thickness versus distance for various water current speeds for oil with sp. gr. = 0.90, μ = 81 cp.

FIGURE 8



23.19

FIGURE 9

Cumulative oil film volume per unit width at various distances and water velocities for oil with sp. gr. = 0.90, μ = 81 cp.

As as example of capacities required, a 600 cfm compressor is capable of supplying adequate air to 100 feet of 1 inch diameter pipe having 1/16 inch diameter orifices positioned 40 feet below the water surface.

As the air bubbles exit from the pipe and rise to the water surface, they impart momentum to the water. This causes vertical water flow which becomes horizontal at the water surface. The surface current generated retains the oil. Figure 10 illustrates the circulation pattern developed. In calm waters the maximum surface current (v_{max}) created is related to the volume flow rate of air per unit length of pipe.

$$v_{max} = k\,(g\,Q)$$

Where

v_{max} - maximum generated surface current ft/sec

k - a constant

g - acceleration due to gravity 32 ft/sec^2

Q - volume flow rate/unit length of manifold

The surface current reaches a maximum at a distance from the center line of the barrier varying between d and d/2 where d is the distance between the undisturbed water surface and the location of the manifold (see Figure 10). It then decreases approximately proportional to $\frac{1}{\sqrt{x}}$ where x = the horizontal distance from the manifold. The effective depth of the surface current (b) is $\frac{d}{4}$ at $x = 1$ and increases linearly for a larger x.

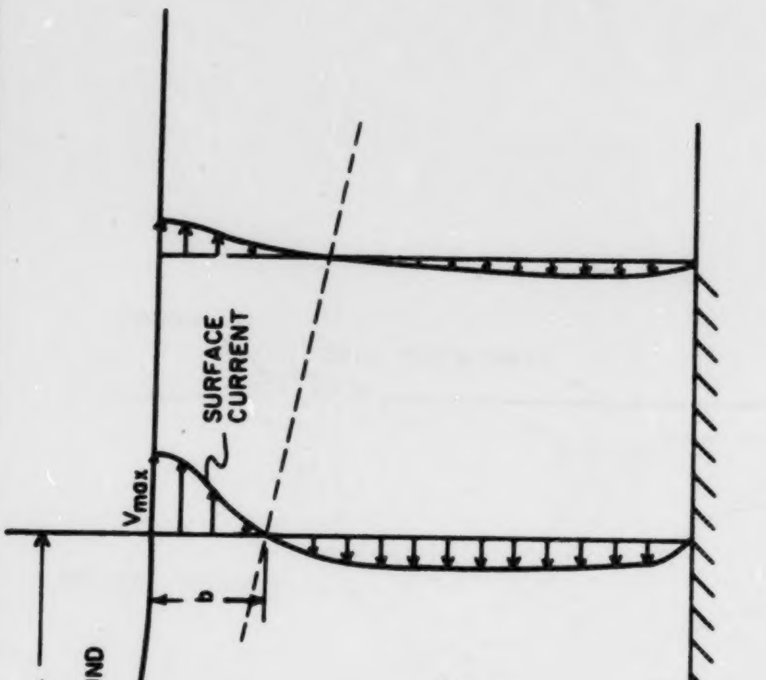
Water currents will cause a distortion in the plume (see Figure 11). This distortion creates a flow pattern which will allow some of the oil to disperse through the bubble screen. The greater the current, the more severe will be the problem. As with a mechanical barrier, oil drops are lost from the bottom of the slick; in this case, because of the turbulent pattern produced.

The information presented is intended to provide the oil pollution control officer with a basis for making recommendations and with the hope that it will provide him with an understanding of the phenomena with which he is dealing. It is expected that his experiences in the field will modify these concepts so that they best serve the needs of his environmental area.

IV BOOM DESIGNS

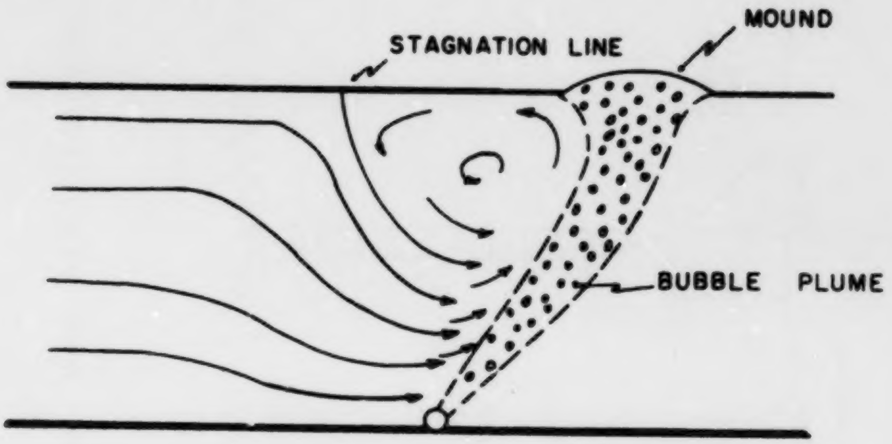
The information having now been presented concerning the factors which should influence boom design and the mechanisms by which they are most likely to fail, what types of barriers are commercially available? What capabilities should the boom have in addition to that most important one of oil retention?

One of the more important is transportability. Cleanup equipment, in general, should be designed for easy transportation from some centralized storage point to the site of a pollution incident. A modular system designed for air transport would be best. Once the equipment is on site, ease of deployment is essential. Regrettably, spills are not in the habit of occurring in ideal weather conditions. The equipment should be designed to provide maximum compatibility with the type of watercraft that are likely to be used in its deployment. In particular, weight handling, towing, and equipment assembly requirements, should be selected with the capabilities of available vessels in mind. The barrier system design should also be as compatible as possible with the other cleanup equipment available. Such a simple thing as non-compatible connecting hitches can destroy a well laid-out spill control program. Last of the major points but by no means least, the containment system should be mutually supporting to the recovery system. Containing an oil spill without matching provisions for optimum physical removal is winning less than half the battle. Wherever possible, components within the barrier system should be readily adaptable for use with the oil removal system. Oil retained and not removed will end up being oil lost to the environment.


SURFACE CURRENT
V_{max}
b
L
MOUND
BUBBLE PLUME
MANIFOLD
x
d

-CIRCULATION PATTERN AND VELOCITY PROFILES IN AIR BARRIER

FIGURE 10


MOUND
STAGNATION LINE
BUBBLE PLUME

- CIRCULATION PATTERN UPSTREAM OF AN AIR BARRIER IN A CURRENT

23.22

FIGURE 11

The types of equipment available may be broadly categorized into three mechanical-type designs and pneumatic barriers. The mechanical barriers are:

1 "Curtain booms" which consist of a surface float acting as a barrier above the surface and a subsurface curtain suspended from it. The curtain is flexible along the vertical axis. It may or may not be stabilized by weights to provide greater resistance to distortion by subsurface currents and have a chain or welded wire rope to transfer stress along the barrier.

2 & 3 Light and heavy "fence booms" have a vertical fence or panel extending both above and below the surface of the water to provide freeboard to counteract wave carryover and draft below the water surface. The flotation assembly is generally bonded to the fence material. The lower edge of the panel is frequently stabilized and strengthened by a cable or chain. The distinction between light and heavy is generally one of size of components and weight.

The general characteristics of these designs are shown in Figure 12.

There are over 50 different commercially-available booms that would fit into these three categories available at the present time. A partial listing is presented in Table 1. More detailed information for one example of each type follows. For additional information, it is suggested that you consult Bibliography reference No. 6.

Curtain Boom - Slickbar

The Slickbar boom manufactured by Slickbar, Inc., Westport, Connecticut, is probably the most popular and most commonly encountered of the curtain booms presently available. All of their present designs consist of a cylindrical-closed cell, foamed-plastic float with a flexible plastic curtain extending approximately half-way into the float. The curtain is secured to the float by a series of stainless steel straps which are riveted to the fin at appropriate intervals depending on float size. Lead ballast is riveted to the bottom of the flexible curtain. The amount and spacing depends upon the environmental conditions expected at the use site. A 1/4 inch stainless steel cable runs the length of each boom section immediately below the plastic float and inside of the stainless steel strapping (see Figure 13).

The booms are available in 4- and 6-inch float diameters with curtain (fin) depths available from 6 to 24 inches. Standard sections are available in 4- and 9-foot float lengths with 6 inches of plastic fin extending beyond each end terminating with stainless steel connector plates. This extends the effective length of each boom to 5 and 10 feet respectively. The sections are connected to provide a continuous barrier.

Prices for the 6-inch diameter float boom in 10-foot lengths complete with ballast weights, ranging from 0.9 to 3.6 pounds per linear foot and having fin depths available from 6 to 24 inches, range from $6.40 to $9.85 per linear foot. These booms are intended for use in relatively quiescent waters of the type found in lakes and protected in harbor areas. A larger and heavier boom with a 12-inch float and 24-inch skirt is presently under development by Slickbar for use in estuarine areas where rougher waters are encountered. This will cost approximately $12.25 per linear foot.

Light Fence Boom - "T-T" Boom

The "T-T" boom was developed in Norway and is presently being manufactured in the United States and marketed by Coastal Services, Inc., a Division of Ocean World. This boom is becoming increasingly popular for use in calm and moderate water conditions. It consists of a vertical section, either 15 or 36 inches deep made of 300 pound per inch tensile strength PVC plastic-coated nylon fabric. Aluminum rods are sewn into the nylon fabric running vertically from top to bottom at either 2- or 3-foot 4-inch spacing. Lead weights are permanently fixed to the fabric at appropriate intervals on the lower edge of the boom generally beside the vertical aluminum rods. Increased ballast may be provided by means of a chain or wire rope threaded through eyelets on the bottom of the curtain. Plastic floats, either rigid-sealed polystyrene type or a closed cell foamed plastic, are attached to the barrier by means of a sash chain with a toggle bar (cotter pin type arrangement). These are generally spaced to fall along the vertical aluminum rods, and are positioned such that two-thirds the height of the barrier is below the water and one-third above. The boom is manufactured in standard lengths of 50 meters (164 feet) which weigh approximately 220 pounds per standard length. One hundred foot standard lengths are also available. A terylene rope running through brass rings fixed on both top and bottom edges of the curtain which made it possible to contract the boom in an accordion-like fashion to reduce the encircled area of an oil spill, is being discontinued due to fouling problems in use. Boom sections are connected by means of a 2-foot overlap of nylon with appropriate hook and tie lines (see Figure 14).

One of the advantages of the barrier is its lightweight and removable, easily attachable floats. Fifty meters of barrier may be stored in a 3 by 4 foot area and launched by one man pulling and attaching floats in a short period of time. When the "T-T" boom is towed in the water to a site for use or towed in a sweeping action to compact an oil slick, the ends of the boom may be equipped with aluminum paravanes for greatest stability and ease in handling. A pair of paravanes weighs approximately 220 pounds.

The prices for the 3-foot barrier, having vertical stiffeners spaced 2 feet on centers with the polystyrene floats, are $9.50 per foot. A pair of aluminum paravanes are $724 per pair and special magnet clamps designed to attach the boom to vessels and sheet pilings are $376 per pair.

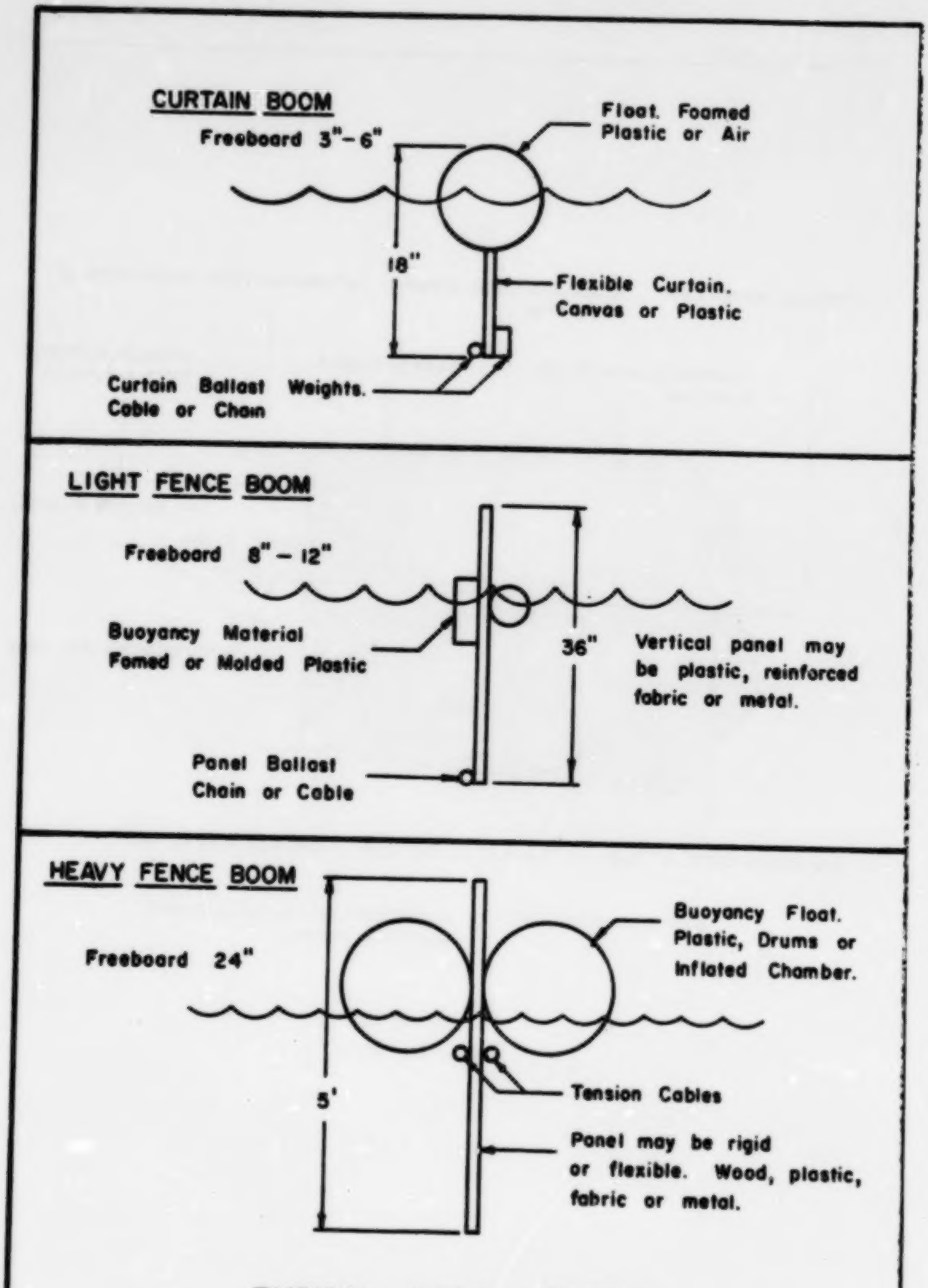
Heavy Fence Boom - "Headrick Boom"

This boom is manufactured by Headrick Industries, Inc., LaCanada, California. It is made up from a series of air inflatable cylinders in varying configurations designed for different sea conditions. The boom cylinders are constructed from high-strength PVC impregnated into a high-strength nylon fabric. A series of air-filled flotation cylinders are positioned above a water-filled submersible cylinder. The water-filled cylinder provides ballast and stability to the total boom assembly. The tubes, as few as two or as many as four, are interconnected continuously by a PVC-coated nylon fabric membrane. A steel cable is permanently enclosed in a loop of the fabric attached to and suspended below the water-filled ballast tube (see Figure 15).

The air tubes are segmented every 50 feet and the water tube every 20 feet so as to provide boom integrity when damaged. The boom is kept stored in a deflated unfilled condition. When needed, it is either unrolled or unfolded and each chamber separately filled with air and water from a surface vessel. The inflatable tubes are reported to retain their air supply for several weeks. If the application situation requires that the boom remain in the water for long periods of time without surveillance, the air tubes may be filled with polyethylene beads, expanded styrofoam or similar materials. Once inserted, however, it is not practical to remove these materials. They also detract one of the barriers more desirable characteristics, its flexibility.

A boom made up of 3 ten-inch diameter air tubes and a 10-inch water tube, weighs approximately 1.8 pounds per foot deflated. Booms will be available in 10, 13, 16 and 22 inch tube sizes. The 22 inch tube unit will weigh 3.6 pounds per foot. The standard length is 1,000 feet which is composed of four 250-foot sections complete with the necessary coupling hardware. These cost $25,000 to $35,000 per standard length.

In addition to the above, some special multipurpose mechanical booms are presently available. Some are designed to provide ab/adsorbing capability, others integral skimming capability along with their oil-retaining function. A partial listing of these is presented in Table 2.


CURTAIN BOOM
Freeboard 3"-6"
Float. Foamed Plastic or Air
18"
Flexible Curtain. Canvas or Plastic
Curtain Ballast Weights. Cable or Chain
LIGHT FENCE BOOM
Freeboard 8" - 12"
Buoyancy Material Fomed or Molded Plastic
36"
Vertical panel may be plastic, reinforced fabric or metal.
Panel Ballast Chain or Cable
HEAVY FENCE BOOM
Freeboard 24"
Buoyancy Float. Plastic, Drums or Inflated Chamber.
5'
Tension Cables
Panel may be rigid or flexible. Wood, plastic, fabric or metal.

TYPICAL BOOM DESIGNS

FIGURE 12

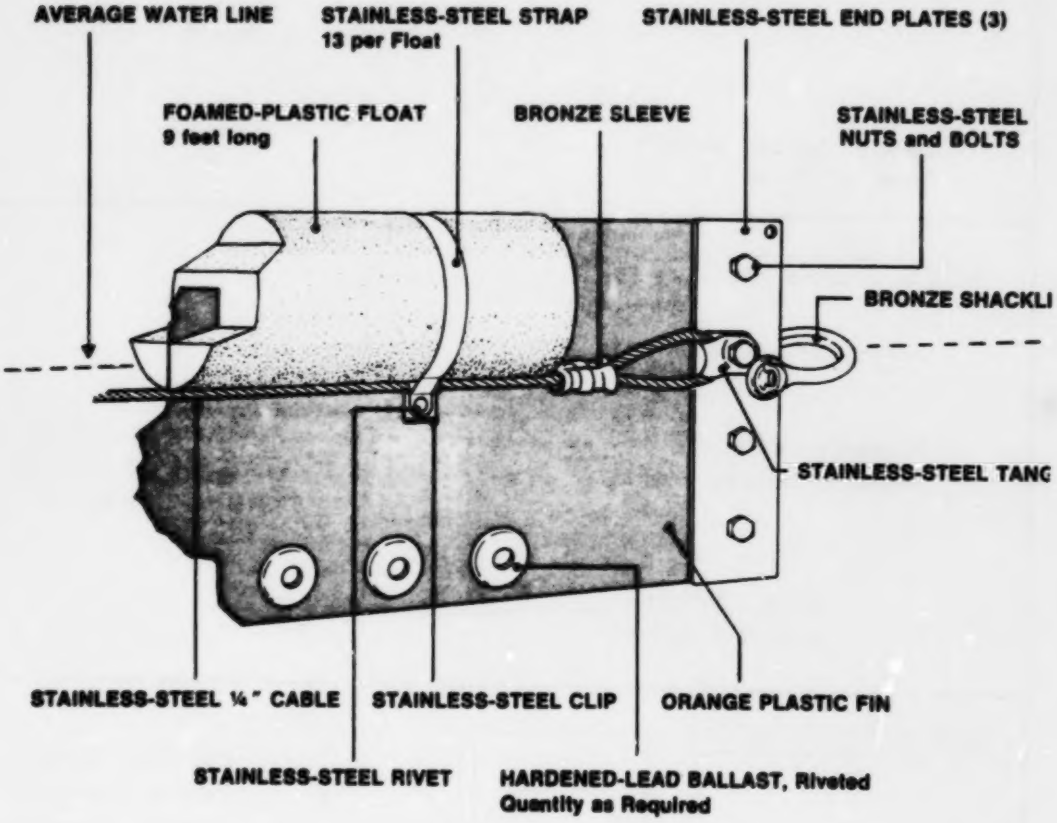
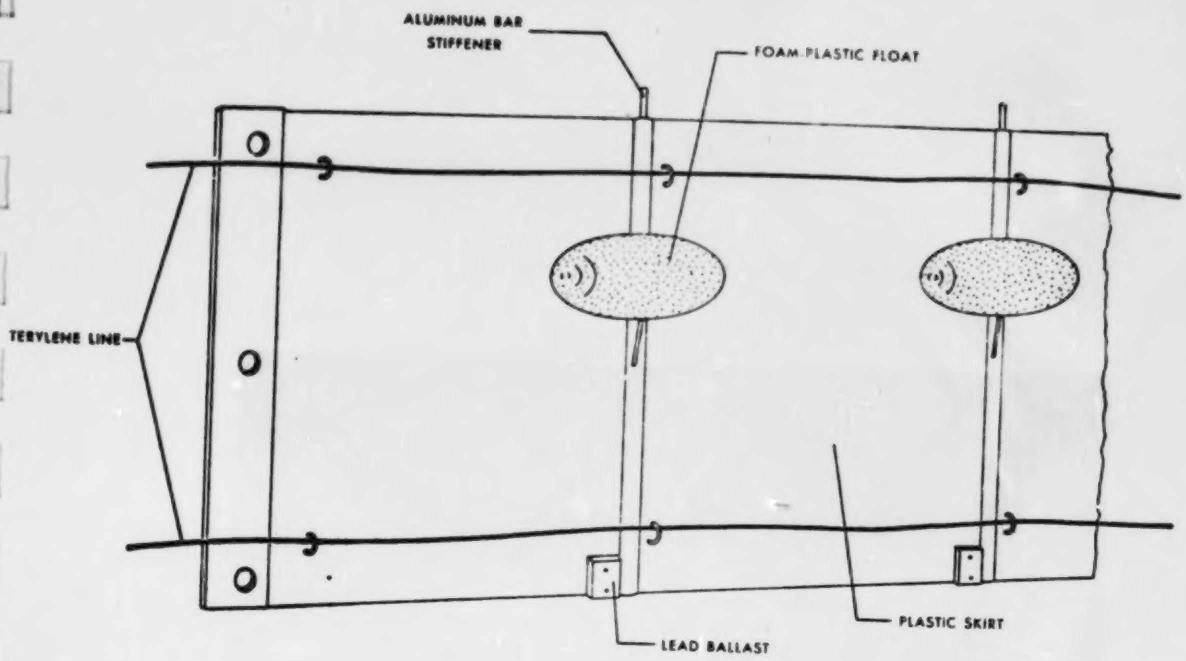

AVERAGE WATER LINE
STAINLESS-STEEL STRAP 13 per Float
STAINLESS-STEEL END PLATES (3)
FOAMED-PLASTIC FLOAT 9 feet long
BRONZE SLEEVE
STAINLESS-STEEL NUTS and BOLTS
BRONZE SHACKLI
STAINLESS-STEEL TANG
STAINLESS-STEEL ¼" CABLE
STAINLESS-STEEL CLIP
ORANGE PLASTIC FIN
STAINLESS-STEEL RIVET
HARDENED-LEAD BALLAST, Riveted Quantity as Required

FIGURE 13
SLICKBAR BOOM


ALUMINUM BAR STIFFENER
FOAM PLASTIC FLOAT
TERYLENE LINE
LEAD BALLAST
PLASTIC SKIRT

T-T BOOM

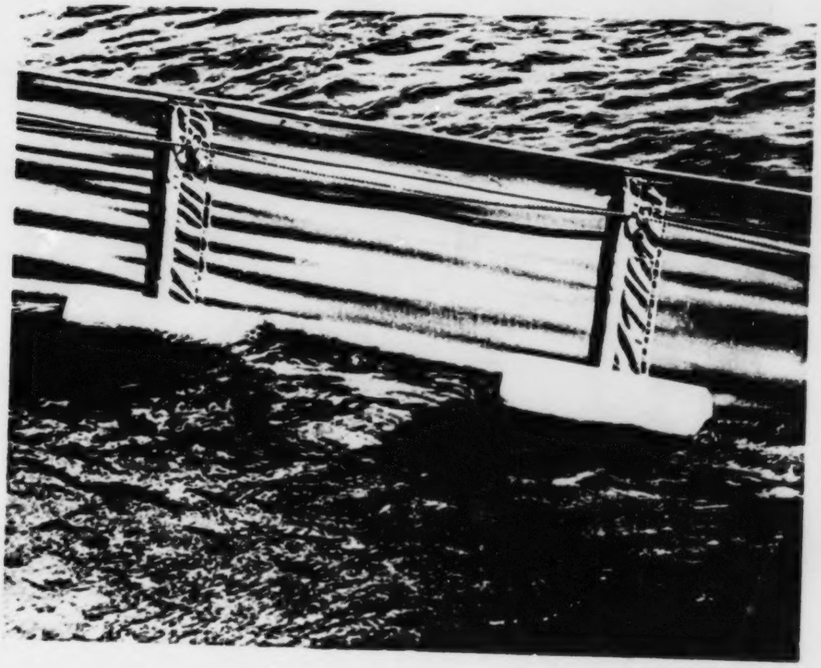
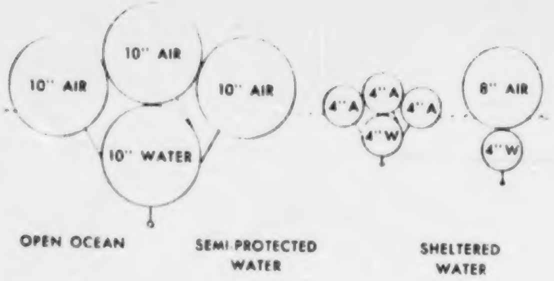


Figure 14
T-T BOOM


10" AIR
10" AIR
10" AIR
10" WATER
4" A
4" A
4" A
4" W
8" AIR
4" W
OPEN OCEAN
SEMI-PROTECTED WATER
SHELTERED WATER

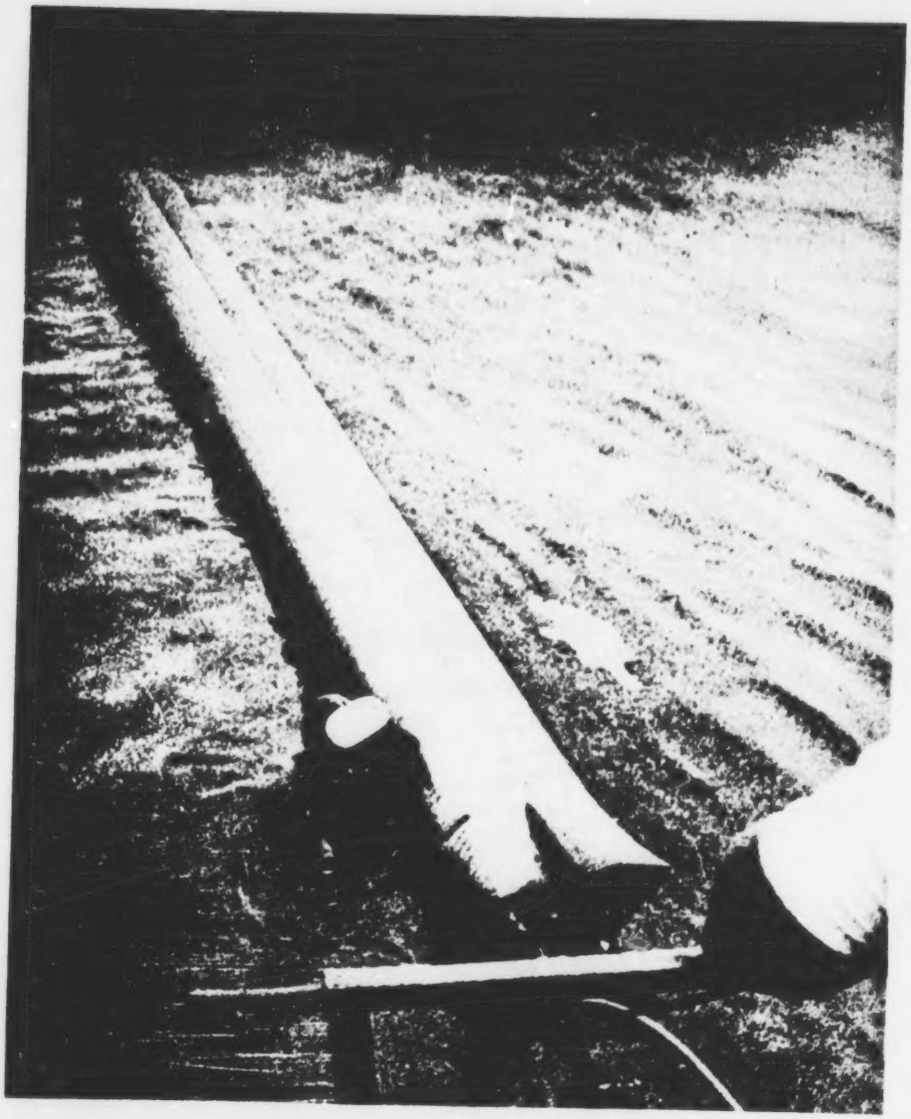


Figure 15
HEADRICK BOOM

TABLE 2 - Calculated Terminal Velocities

a. Interfacial Tension = 10 Dynes/Cm

Drop Diam. In.	Oil Specific Gravity .8	.85	.9	.95	.97	.98	.99
0.0010	0.003566	0.002916	0.002195	0.001351	0.000945	0.000711	0.000438
0.0020	0.007133	0.005832	0.004391	0.002703	0.001890	0.001423	0.000876
0.0040	0.014266	0.011664	0.008782	0.005406	0.003781	0.002846	0.001752
0.0065	0.023183	0.018955	0.014271	0.008785	0.006144	0.004626	0.002847
0.0100	0.035668	0.029162	0.021956	0.013516	0.009452	0.007117	0.004381
0.0200	0.071317	0.058317	0.043911	0.027032	0.018906	0.014234	0.008762
0.0400	0.141914	0.116273	0.087688	0.054041	0.037806	0.028467	0.017525
0.0650	0.223815	0.185383	0.141099	0.087549	0.061357	0.046231	0.028473
0.1000	0.307306	0.263190	0.207284	0.132567	0.093750	0.070878	0.043759
0.2000	0.369552	0.339260	0.295863	0.221511	0.170109	0.134129	0.085882
0.4000	0.000000	0.000000	0.000000	0.252218	0.218110	0.190420	0.142903
0.6500	0.000000	0.000000	0.000000	0.000000	0.000000	0.195046	0.161475
1.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.159074

b. Interfacial Tension = 20 Dynes/Cm

Drop Diam. In.	Oil Specific Gravity .8	.85	.9	.95	.97	.98	.99
0.0010	0.003327	0.002720	0.002048	0.001261	0.000882	0.000664	0.000409
0.0020	0.006655	0.005441	0.004096	0.002522	0.001764	0.001328	0.000817
0.0040	0.013310	0.010883	0.008193	0.005044	0.003527	0.002656	0.001635
0.0065	0.021630	0.017685	0.013315	0.008196	0.005732	0.004316	0.002657
0.0100	0.033278	0.027209	0.020485	0.012610	0.008819	0.006640	0.004087
0.0200	0.066551	0.054416	0.040971	0.025221	0.017639	0.013280	0.008175
0.0400	0.132791	0.108678	0.081887	0.050435	0.035277	0.026561	0.016351
0.0650	0.212642	0.174993	0.132451	0.081841	0.057293	0.043151	0.026569
0.1000	0.306552	0.257795	0.199049	0.124954	0.087860	0.066280	0.040856
0.2000	0.411404	0.371929	0.316105	0.224870	0.166831	0.128913	0.080979
0.4000	0.000000	0.000000	0.342575	0.283933	0.239408	0.203749	0.145302
0.6500	0.000000	0.000000	0.000000	0.000000	0.246480	0.221535	0.177680
1.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.182599

c. Interfacial Tension = 30 Dynes/Cm

Drop Diam. In.	Oil Specific Gravity .8	.85	.9	.95	.97	.98	.99
0.0010	0.003194	0.002611	0.001966	0.001210	0.000846	0.000637	0.000392
0.0020	0.006389	0.005223	0.003933	0.002421	0.001693	0.001275	0.000785
0.0040	0.012778	0.010447	0.007866	0.004842	0.003386	0.002549	0.001569
0.0065	0.020765	0.016978	0.012782	0.007868	0.005503	0.004143	0.002550
0.0100	0.031948	0.026121	0.019666	0.012106	0.008466	0.006374	0.003924
0.0200	0.063894	0.052242	0.039334	0.024213	0.016934	0.012749	0.007848
0.0400	0.127600	0.104392	0.078636	0.048422	0.033868	0.025500	0.015697
0.0650	0.205385	0.168641	0.127405	0.078617	0.055016	0.041431	0.025508
0.1000	0.302108	0.251981	0.193011	0.120358	0.084467	0.063675	0.039231
0.2000	0.433290	0.387498	0.323712	0.223538	0.163156	0.125044	0.078010
0.4000	0.000000	0.409167	0.370111	0.301460	0.249643	0.208851	0.144561
0.6500	0.000000	0.000000	0.000000	0.301918	0.265958	0.236749	0.185595
1.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.233599	0.196671

d. Interfacial Tension - 40 Dynes/Cm

Drop Diam. In.	Oil Specific Gravity .8	.85	.9	.95	.97	.98	.99
0.0010	0.003104	0.002538	0.001911	0.001176	0.000823	0.000619	0.000381
0.0020	0.006209	0.005076	0.003822	0.002353	0.001645	0.001239	0.000763
0.0040	0.012419	0.010153	0.007644	0.004706	0.003291	0.002478	0.001525
0.0065	0.020181	0.016500	0.012423	0.007647	0.005348	0.004027	0.002479
0.0100	0.031049	0.025386	0.019113	0.011765	0.008228	0.006195	0.003813
0.0200	0.062098	0.050773	0.038227	0.023532	0.016457	0.012391	0.007627
0.0400	0.124065	0.101483	0.076434	0.047062	0.032916	0.024783	0.015256
0.0650	0.200198	0.164199	0.123937	0.076427	0.053475	0.040268	0.024790
0.1000	0.297655	0.247139	0.188509	0.117160	0.082147	0.061905	0.038132
0.2000	0.446685	0.396188	0.326847	0.221364	0.160068	0.122147	0.075942
0.4000	0.463371	0.432937	0.359363	0.312749	0.255406	0.211015	0.143226
0.6500	0.000000	0.000000	0.000000	0.319628	0.279508	0.246891	0.190127
1.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.247583	0.206358

In many cases, a commercial boom is not available when an oil pollution incident occurs and maximum use of available materials must be made to provide at least temporary containment or diversion capability until better equipment can be brought to the site. A partial listing of homemade barrier types is presented in Table 3. One of the more famous of these is the Navy boom shown in Figure 16.

The use of air curtains for oil slick containment was discussed in Section 3 and an example of one type presented. Submersible Systems, Inc., Palm Beach, Florida, manufactures an air barrier system. In general it is designed for the environmental conditions existing at the use location. One unit placed in operation consisted of 20-foot lengths of 1-inch inside diameter aluminum pipe with 1/16 inch diameter holes spaced every 6 inches along its length. The sections were connected with a semi-flexible compression-type coupling. Air was supplied by a 600 cfm compressor operating at 45 psi. The cost for this type of barrier will vary with the site location.

V EXAMPLE OF USE

The following is a narrative presentation illustrating one possible use of oil booms for the control of an oil spill. It does not specifically represent any singular pollution incident but rather reflects techniques which met with at least some degree of success in actual incidents.

A vessel with a cargo of crude oil struck a submerged object in the navigation channel approximately 4 miles from shore. The forward center and starboard tanks were holed and approximately 1,000 barrels of a fairly heavy crude oil lost before leakage was controlled. At present the sea is calm and the current immediately off of the channel where the oil was lost is approximately 2 knots. The wind is blowing steadily from the south at about 9 knots and will move the oil slick northerly toward a beach area. Making use of information previously presented, it is determined that oil will begin reaching the beach area in about 12 hours. Considering the time involved, it is likely that at least part of the slick will reach the shoreface area and that some procedures will have to be implemented for its protection. You want to get equipment out to the site of the slick as soon as possible to remove as much as possible before it does reach the beach area. (See Figure A)

You have two skimmers available one of 400 gpm and one of 200 gpm capacity. Work boats, fishing boats, various types of absorbers, and 1,500 feet of light fence boom, and 1,000 feet of pnuematic barrier. Making use of the information previously presented in Sections 2 and 3, you determine that your best defense barrier will not be capable of holding the oil offshore in a fixed position while you pump it off the water. You have also determined, based on the relative wind velocity, current situation, and the type of spread to be expected from this particular grade of oil, that without some type of containment, you will have a thin film of oil coming ashore within 12 to 14 hours.

The following is one approach that might be followed. Put your larger skimmer on a work boat along with 900 feet of the fence type barrier and proceed out to the site of the slick. Set up your equipment as shown in Figure B. The skimmer should be positioned so as to work in the pool of oil collected by the barrier. Note that one end of the boom is held close alongside the work boat and skimmer with a small boat out at the other end. The oil will collect along the wind side of the boom and then be diverted along the boom to the skimmer. The skimmer should be operated at capacity with the oil-water mix being discharged to some type of storage facility for oil-water separation. Note that -

1 There must be an oil tight connection between the skimming unit and the boom at a and the boom and the work boat at b.

2 The position of the upwind end of the boom and the work boat itself must be changed quickly as the wind shifts. The flow of the slick must continue into the area between the boom and the pump boat.

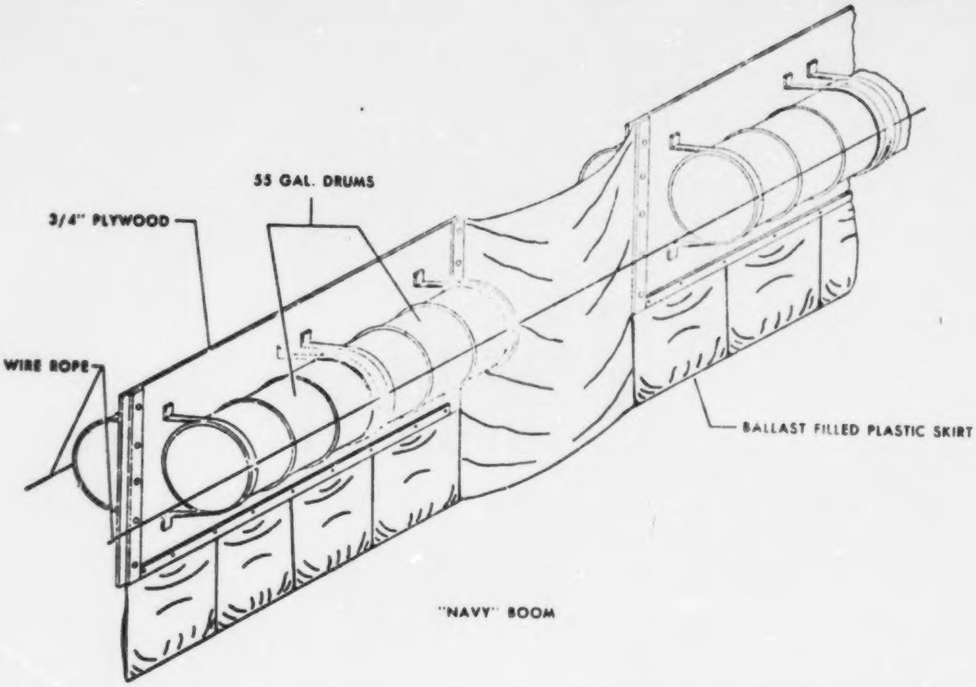
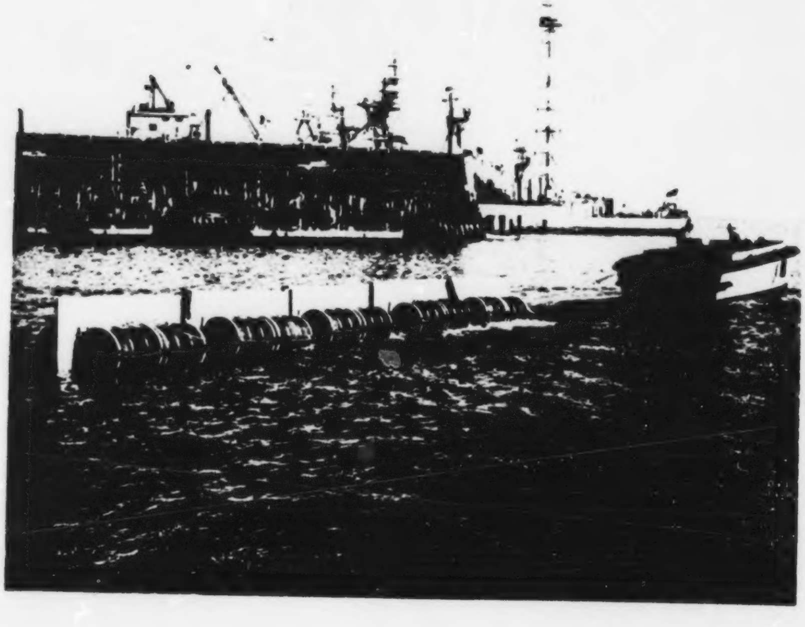

55 GAL. DRUMS
3/4" PLYWOOD
1/2" WIRE ROPE
BALLAST FILLED PLASTIC SKIRT
"NAVY" BOOM

Figure 16
NAVY BOOM



SUMMARY TABLE 2

MULTIPURPOSE BOOMS

Boom	Stage of Development	Cost $/Ft.	Manufacturer
1. ICI Oil Absorbing Boom	In Production	$6.75 - 7.45	ICI Fibres Ltd. Harrogate Yorkshire, England
2. Roscoff Heavy and Light-Weight Booms	Used at Torrey Canyon Spill	Unknown	Marine Biological Laboratory Roscoff North Brittany, France
3. Sea Serpent	Under Development	Unknown	Johns-Manville Co. 22 East 40th Street New York, New York 10016
4. Skimmer Boom	Patent Pending	Unknown	E. P. Hall FWPCA Washington, D.C. 20242

SUMMARY TABLE 3

IMPROVISED BOOMS

	Type of Boom	Location Where It Was Used
1.	Cork-Filled Boom	Norfolk, Virginia
2.	Cork-Float Boom	Port Hueneme, California
3.	Fire Hose Boom	Quiescent Waters
4.	Puerto Rican Boom	Ocean Eagle Oil Spill
5.	Rubber Bladder Boom	Helford River, Great Britain
6.	Rubber Tire Boom	Torrey Canyon Oil Spill
7.	Steel Pipe Boom	Philadelphia, Pennsylvania
8.	U.S. Navy Boom	Long Beach, California Chevron Spill, 1970
9.	Wooden Float Boom	Pearl Harbor, Hawaii
10.	Wooden Timber Boom	Quiescent Waters
11.	Wooden V-Boom	Peros Gyiroc, France

3 The angle between the wind direction and the boom should not be greater than 20 degrees. With more angle the boom will tend to develop a belly in its shape and oil will be lost under the boom.

4 The work boat and the boat holding the leading edge of your boom are drifting at a speed which you have previously determined will not allow oil to be lost under the barrier. This speed will, of course, be adjusted based on on-site conditions.

No comments will be made about the type of skimmer, oil-water separation system or storage system. These are obviously a very important concern and will control the speed at which the recovery system will move with the slick to prevent loss. Information concerning these is presented in other parts of the training manual.

You now have two other problems to contend with-

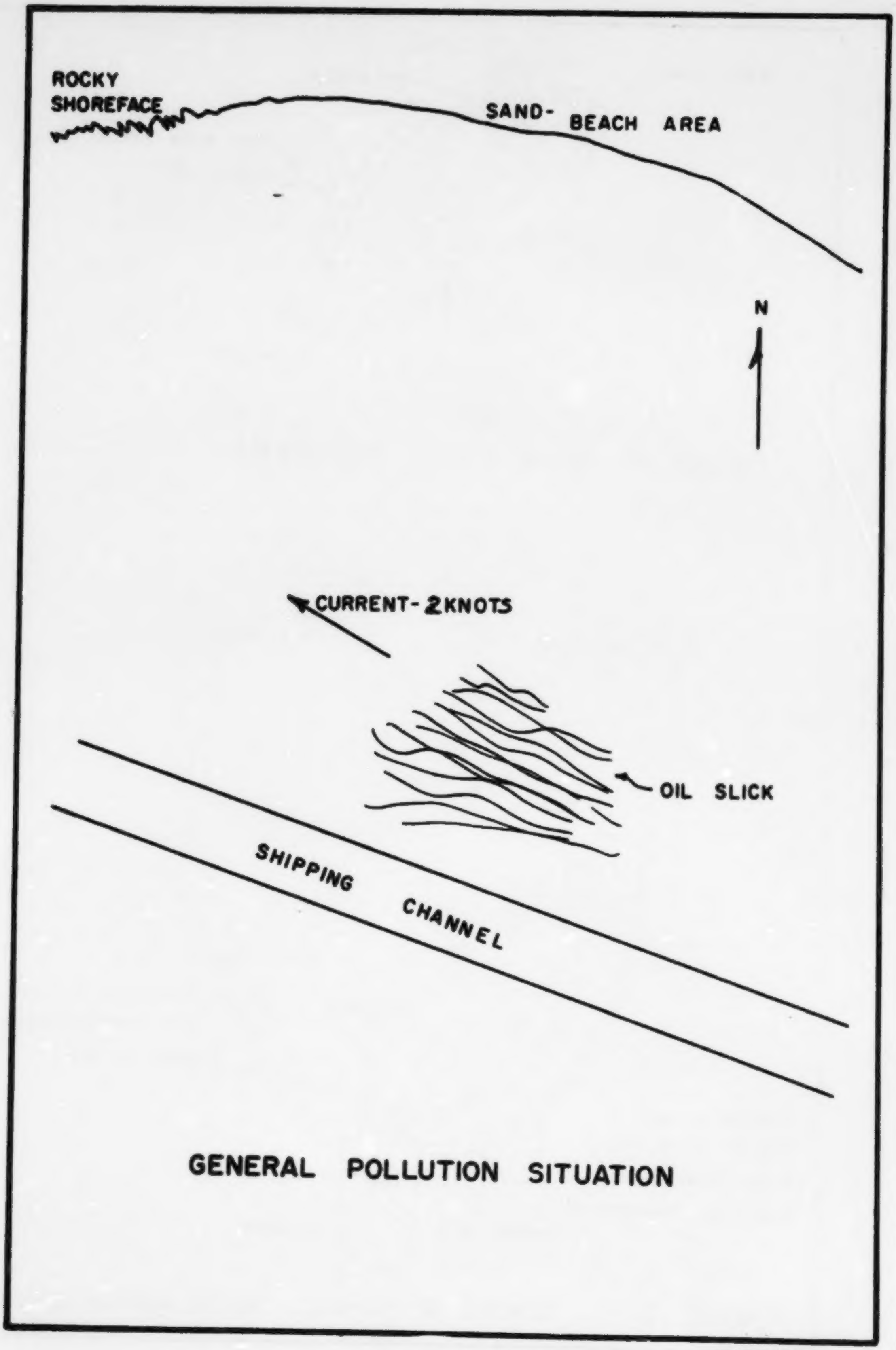
1 It is obvious from your calculations that it will not be possible to remove all of the oil from the water surface before it gets into the beach area.

2 The slick is not remaining as one integral mass and portions of it are breaking away and being left behind in the bay.

Next, consider handling those portions of the slick being left behind in the bay. Two small fishing boats and a contractor's work boat having flat deck space in the bow, have been contracted for and the remaining fence boom and the small skimmer mounted on them. These can be arranged as shown in Figure C. The bow string tension line attached to No. 2 boat reduces the sharp bend that would otherwise exist in the boom and eliminates turbulence and oil loss at the point where the boom would ordinarily bend when it joins the work barge as with No. 1 boat. With the boom system so deployed, this work group begins chasing those slicks left behind and using the small skimmer, pumps them to appropriate storage. The operating speed of this group is controlled by the structural strength of the boom in question which has been considerably increased with the bow string arrangement, and the thickness of oil being recovered at any one time. Remember that the wind should be used to your advantage whenever possible to assist in diverting the oil down the funnel. Note that radio communication among the three boats is essential for proper functioning of this system.

It is now necessary to consider setting up some type of protection at the beach area. As all that is left is the air barrier, this will have to be implemented. The air barrier should be placed on the bottom at a distance from shore that will provide it with a minimum of 10 feet of water at low tide. The air supply can come from a diesel powered air compressor mounted on a barge or convenient headland if available. Taking a look at the area, the most difficult area to clean is going to be the rocky section on the northwest side of the beach. The air barrier should be set up so as to divert the oil from the rocky section toward the beach area. A physical absorber should be placed along the tidal zone of the beach area to absorb as much of the oil as possible to prevent penetration into the beach sand. A float with some type of anchoring system has been established a short distance from the end of the air barrier so that the work barge and skimmer, when they arrive at this point, will have somewhere to attach their fence boom. Initially, the oil that has gotten away from the two skimmers working in the bay will be diverted toward the beach. When the main skimming apparatus arrives on scene, the oil will be diverted along the air barrier to the fixed mechanical barrier to the skimmer. (See Figure D)

This is a simplified discussion of boom placement which does not attempt to take into account all of the variables which might be encountered. It is cited as an example of some of the procedures which could be implemented making use of the information presented in Sections I through IV. It must be emphasized, that getting the boom out and corralling the mess is only the beginning. The very difficult task of removing the material from the environment and its ultimate disposal has to be as well considered and planned out as your boom purchasing and implementation program. There would have been nothing more useless, for example, than taking all of the barrier that you had available in the incident cited above and drawing it across the beach area and then sitting back and watching the oil pile up along its face to finally run under and/or over it to contaminate the beach area. The best designed equipment, if not properly used, will not do the job.


ROCKY SHOREFACE
SAND- BEACH AREA
N
CURRENT- 2KNOTS
OIL SLICK
SHIPPING CHANNEL

GENERAL POLLUTION SITUATION

23.35

FIGURE A

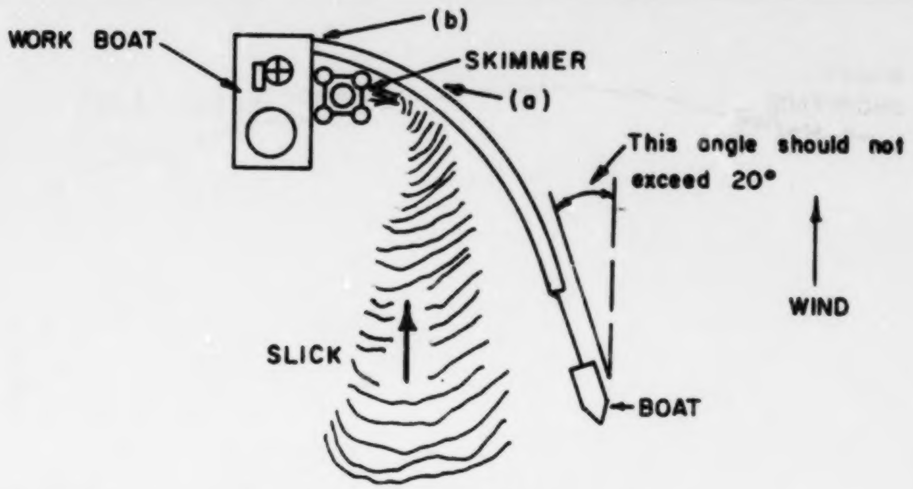

WORK BOAT
(b)
SKIMMER
(a)
This angle should not exceed 20°
WIND
SLICK
BOAT

FIGURE B. MAIN SLICK RECOVERY

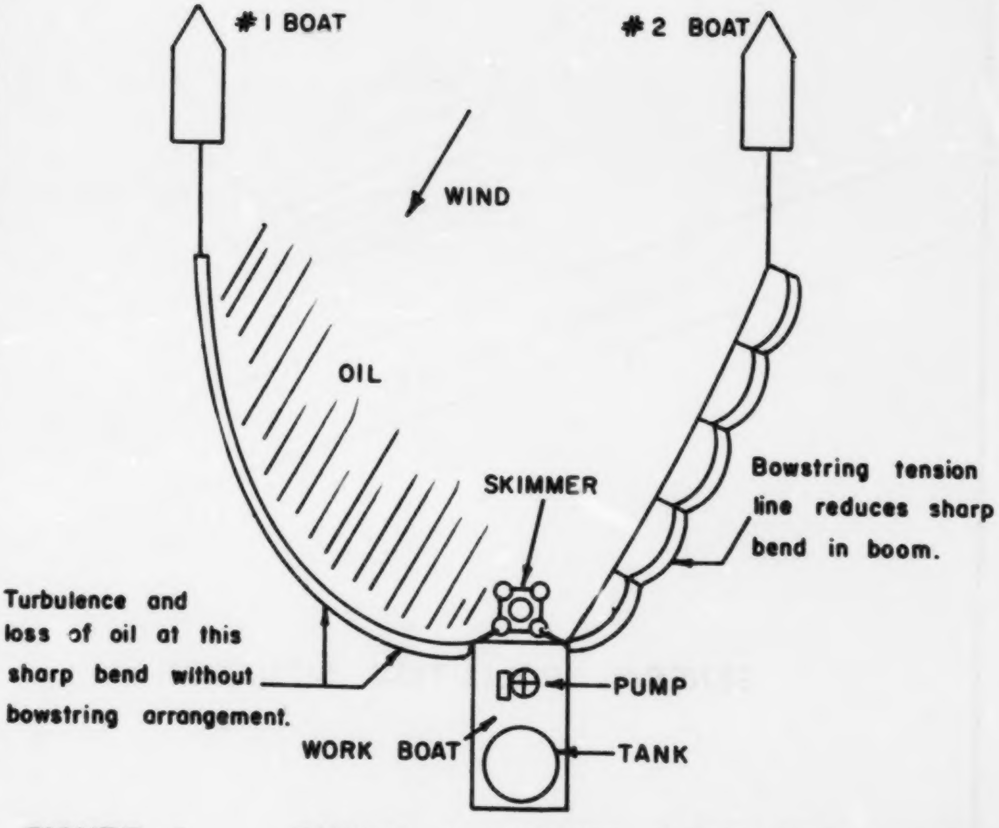
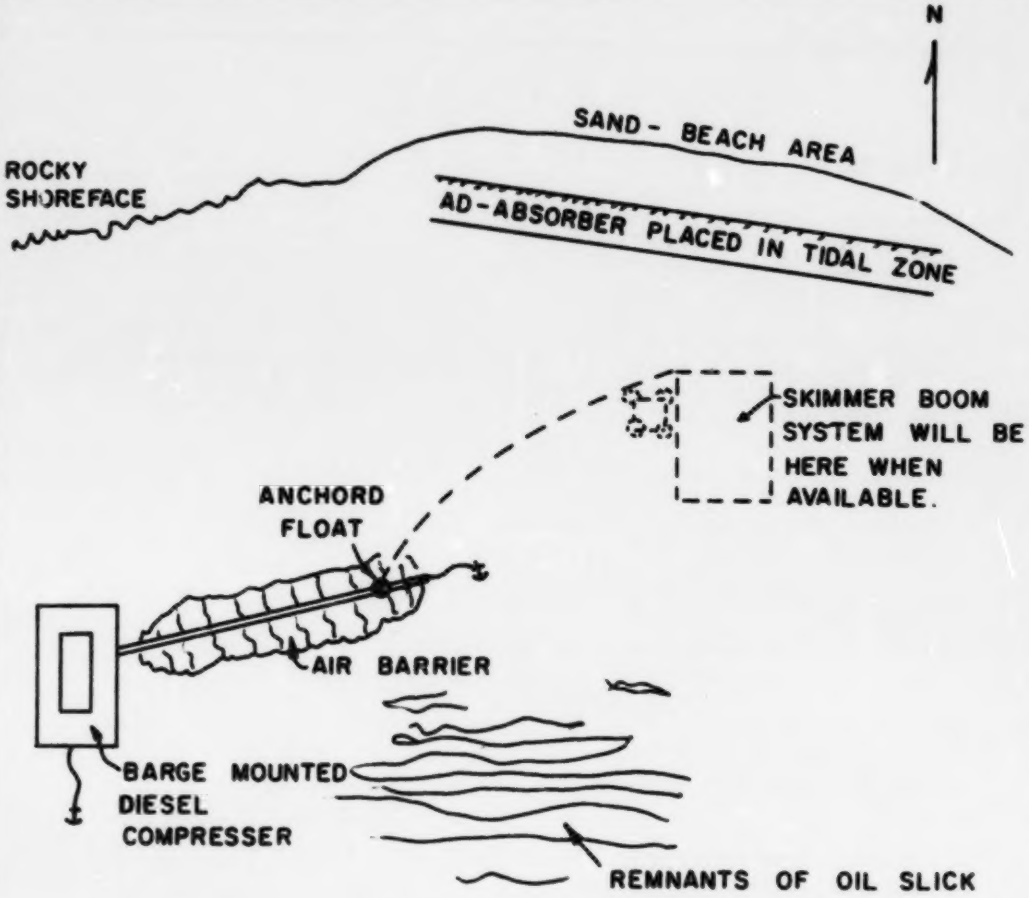

#1 BOAT
#2 BOAT
WIND
OIL
SKIMMER
Bowstring tension line reduces sharp bend in boom.
Turbulence and loss of oil at this sharp bend without bowstring arrangement.
PUMP
WORK BOAT
TANK

FIGURE C. TOWING A FUNNEL BOOM ARRANGEMENT


N
ROCKY SHOREFACE
SAND - BEACH AREA
AD-ABSORBER PLACED IN TIDAL ZONE
SKIMMER BOOM SYSTEM WILL BE HERE WHEN AVAILABLE.
ANCHORD FLOAT
AIR BARRIER
BARGE MOUNTED DIESEL COMPRESSER
REMNANTS OF OIL SLICK

SHOREFACE PROTECTION SCHEME

FIGURE D

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4 Lehr, W.E. and Schorer, J.O. Design Requirements for Booms. Joint FWPCA-API Conference Proceedings. New York. December 1969.

5 Milz, E.A. An Evaluation-Oil Spill Control Equipment & Techniques. API 21st Annual Pipeline Conference. Dallas. April 1970.

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8 Testing and Evaluation of Oil Spill Recovery Equipment. Water Pollution Control Research Series, Grant No. 150-80-DOZ, Federal Water Quality. 1970.

9 Wicks, M. Fluid Dynamics of Floating Oil Containment by Mechanical Barriers in the Presence of Water Currents. Joint FWPCA-API Conference Proceedings. New York. December 1969.

This outline was prepared by Thomas W. Devine, Sanitary Engineer, New England Basins Office, Region I, Environmental Protection Agency.

TREATMENT OF OIL SPILLS

Oil Skimming Devices

I INTRODUCTION

A Once an oil spill has occurred, the most positive approach to protect the environment is to physically remove the oil from the water. This may be accomplished, to a more or less degree, by the use of mechanical pickup devices commonly called "skimmers". The numerous types of skimmers presently under development do not permit a presentation on each particular unit. If the reader desires information on particular devices, the Edison Water Quality Laboratory's May 1970 publication titled, "Oil Skimming Devices", is recommended.

B The ideal oil skimmer should be designed for:

1 Easy handling

2 Easy operation

3 Low maintenance

4 Ability to withstand rough handling

5 Versatility to operate in various wave and current situations

6 Ability to skim oil at a high oil to water ratio

The present day skimmers are generally designed to emphasize one or more of the above characteristics. Before purchasing a skimmer for use in a particular area, the buyer should know what he requires and which characteristics best suit his needs.

The reports and studies which are referenced at the end of this outline evaluate oil skimming devices. Using this information we will now direct our effort towards selecting pieces of equipment which will meet particular needs.

II THE BASIC OIL SKIMMING DEVICES

A Mechanical devices which physically remove oil from the water's surface contain three basic components:

1 The pickup head

2 The pump system

3 The oil/water separator

These components may be constructed as one unit, separate units or any combination of the three. A brief discussion of each follows.

B The pickup head - Figure 1 shows the three most popular types of pickup heads in use today:

1 Weir type

2 Floating suction type

3 Adsorbent surface type

The weir type removes oil from the water's surface by allowing the oil to overflow a weir into a collecting device and holding the water back against the weir. The efficiency of weir pickup heads is highly dependent on calm water conditions and an adequate thickness of oil; however, viscosity of the oil is not too important. Even so, a certain amount of water is drawn over the weir making it necessary to provide a means for separating the oil and water. Therefore, this type of pickup head would be used in areas where the water conditions are generally calm and the oil slick thickness can be maintained at greater than 1/4 inch. The type of oil is not a major consideration.

The floating suction type operates on the same principal as the household vacuum cleaner. The unit is generally small in size and is connected to the oil/water separation section by either a suction or a pressure hose. The floating head may limit the amount of water either by a system of weirs or by the design of the intake openings. Water surface conditions and oil viscosity greatly affect the efficiency of these devices. The floating suction heads are well suited for working in tight areas such as around piers and ships. Debris and sorbents tend to clog these units quite readily and therefore must be considered.

The adsorbent surface type operate on the principle that a hydrophobic and oleophilic surface will be preferentially wetted by oil and not water. As the adsorbent surface is drawn through the slick oil will cling to it. This oil is then removed either by rollers, wringers or wiper blades. The surfaces are constructed of aluminum or various oleophilic foams or fibers.

The problem of additional oil/water separation is eliminated with these devices. They have been tested successfully in wave heights up to 2 feet. Debris interferes with their efficiency and in some cases may cause severe damage. These units would be best suited for open harbor use. The type of oil to be collected determines the type of adsorbent surface required. For example, heavy oils tend to clog foams and fibers and light oils are not picked up efficiently on aluminum surfaces.

We have pointed out several parameters which will effect the selection of a particular pickup head:

1 Type of oil

2 Sea state - waves and currents

3 Debris - sorbents

4 Physical restrictions - piers, etc.

5 Equipment available to separate oil/water mixtures

C The Pump System - Pumps and other accessories used with skimmers need to have the following features incorporated in their designs:

1 Dependability - carburetors, magnetos, points and plugs need to be protected against ocean air and salt spray.

2 Portability - easy to transport. Equipment must have good balance and good handles for manual lifting, and sling attachments for mechanical lifting.

3 Quick and positive coupling and uncoupling of hoses and other connections is essential.

4 Low maintenance costs and easy cleaning and storage arrangements.

5 Ability to work in gangs to handle increased volumes.

6 Protection from clogging due to debris or sorbents.

The selection of the type of pump is very important. A centrifugal pump can handle large volumes of flow which may be required to remove very thin slicks. However, this type of pump imparts tremendous mixing energy and produces an oil/water emulsion which may not separate satisfactorily in the settling chamber. On the other hand, positive displacement pumps, such as diaphragm or piston pumps, while they cannot handle as large a flow, do not mix or emulsify the oil/water mixture. The efficiency of the settling chamber is thus increased. Positive displacement pumps also are very easy to repair, unclog and maintain and do not require priming.

Here, the choice of a pump depends on the volume of water flow required, the size of the oil/water separator available and the expected amount of maintenance assistance available. Based on past experience, the chief cause for an unsuccessful oil skimming operation has been due to failure in the pumping system.

D **The Oil/Water Separator** - is essentially a settling chamber where collected oil separates by gravity from collected water. A system of weirs and baffles may be employed to facilitate separation. The water may either be pumped out or forced out by gravity. The oil is normally pumped out when the tank has reached its oil storage capacity. The separator may be nothing more than a tank truck or it may be specially designed to meet particular needs.

Normally, the weir type and the floating suction head type pickup units require an oil/water separator. Likewise, if a centrifugal pump is used, a separator is usually required.

III SUMMARY

A The basic oil skimmer is composed of three units:

1 Pickup head

2 Pump system

3 Oil/water separator

There are three basic pickup heads in use today:

1 Weir type

2 Floating suction head type

3 Adsorbent surface type

The pump system usually employs either of two types of pumps:

1 Centrifugal pump

2 Positive displacement pump

An oil/water separator is required to separate the large amounts of water usually picked up with the oil slick.

B Tests and experiences have indicated that present day skimmers do not operate efficiently in wave heights greater than 1.5 to 2.0 feet or in currents greater than 1.0 to 1.5 feet per second.

C Prior to purchasing an oil skimmer, the buyer should determine physical restrictions, such as piers, shallow water, marshes, etc., estimate the quantities and types of oil to be handled, investigate the local weather conditions and become familiar with the body of water in which the proposed skimmer is to be used. Using this information the proper oil skimmer can then be selected.

REFERENCES

1 Milz, E.A. An Evaluation of Oil Spill Control Equipment and Techniques, April 14, 1970, Shell Pipe Line Corporation, P.O. Box 2648, Houston, Texas 77001.

2 Proceedings of the Joint Conference on Prevention and Control of Oil Spills, December 1969, American Petroleum Institute, 1271 Avenue of the Americas, New York, N.Y. 10020.

3 Oil Skimming Devices, Edison Water Quality Laboratory, May 1970, Planning and Resources Office, Office of Research and Development, EPA, Washington, D.C. 20242.

This outline was prepared by J.S. Dorrler, Acting Chief, Oil Pollution R & D, Edison Water Quality Laboratory, Office of Water Programs, Edison, NJ 08817.

OIL WATER SEPARATOR DESIGN

I INTRODUCTION

Numerous characteristics of oil and of water affect the nature of oil in water, and these characteristics, in addition to the conditions under which the separation takes place, determine the type of oil/water separator that is most appropriate for a given application. This outline examines three classes of application of oil/water separators: oil spill control, bilge and ballast separation and industrial process waste water separation.

II VARIABLES OF OIL

For the purposes of this discussion, oils vary according to their source: spill, bilge, ballast or process water contamination.

A Spilled Oil

Crude or distillate product

Specific gravity: 0.750 to 1.05

Viscosity: From consistancy of gasoline or light fuel oil to that of mayonnaise ("chocolate mousse")

Viscosity and density may change with weathering

Crude may contain surfactants which are naturally occurring or the result of oxidation.

Spilled oil on open sea usually relatively free of foreign contamination, unless sorbents are used, but in harbor areas, contamination by particulate matter may present a problem.

B Bilge Oils

Result of leakage from hydraulic, fuel and lubricating oil systems.

Contains high quantity of surfactants and other additives.

Foreign contamination with oil-wet rust particles, dirt, scale.

C Ballast Oils

Tanker service - usually crude oils

Dry cargo service - usually Bunker "C" oil

Some Bunker "C" oils in west coast and Hawaii areas have density greater than that of water.

Viscosity may be high, particularly Bunker "C" in cold weather.

Some particulate matter contamination, paint, rust and scale from inside the tank.

D Industrial Process Oils

Very wide range of oil viscosities, densities, additives.

Typical examples: condensate return, lubricating and cooling oils in metal cutting operations, refinery operations, offshore platform operations.

Oil may contain foreign contaminants - chemicals, particulate matter, etc.

III VARIABLES OF WATER

Variations in the properties of the water affect the nature of the oil in or on the water, the dispersion that is formed when the oily water is subjected to turbulence, and the tendency for that dispersion to be separated from the water.

Specific gravity:	Fresh: 1:00; salt: 1.03; affects buoyancy of oil particles
Turbidity:	May cause oils to ad/absorb on particulate matter.
Temperature:	Affects temperature of oil, hence oil viscosity affects water viscosity, hence drag of water on oil particles.
Salinity and pH:	May have effects on the stability of oil particles.
Chemicals:	Industrial wastewaters may have effects on oil particle stabilities.

IV OIL IN WATER

Oil in water exists as a distribution of discreet, spherical droplets. The nature of the distribution, that is, the percentage of droplets in each of a given set of size ranges, is determined by the dispersibility of the oil, the level of turbulence to which the oil/water combination is subjected, and the type and quantity of surfactants present. The stability of the droplets, i.e., their tendency to rise to the top of the water column and/or coalesce depends on many factors, some of which are the droplet size, the type and quantity of surfactants present, density differential, water viscosity and pH and particulate matter in the water.

Considering the various ways oil may exist in water, a few definitions are appropriate here. For our purposes, the size and variation in stability of an oil particle suspended in water are our principal criteria for description of oil in water.

A Emulsion shall mean a distribution of oil particles of a size range measured in microns, which has been rendered stable by the presence of one or more emulsifying agents (surfactants) which alter the normal interfacial environment between the dispersed phase and the continuous phase.

B Dispersion shall mean a distribution of oil particles of a size range measured in microns to millimeters with no surfactants present. The smallest of these particles may be stable in water due to electrostatic forces, molecular forces and viscous drag. The larger particles (.25 mm diameter and larger) are susceptible to separation from water by most commercially available separators, by physical means alone, i.e., without chemical additions.

C Mixture shall mean oil particles in water in a size range measured in millimeters to centimeters, with little or no tendency toward stability, and easily separated by physical means.

D Viscosity shall mean the resistance offered by a fluid to flow, and shall be a measure of the combined effects of adhesion and cohesion.

E Dispersibility shall be the tendency for the oil in an oil particle size distribution in water to shear to small size particles when subjected to a given level of turblence. For a given level of turbulence, an oil of high dispersibility will have a particle size distribution in which there is a high percentage of small particles. An oil of low dispersibility, for the same level of turbulence, will have a high percentage of large particles in its distribution. The dispersibility of an oil depends on its viscosity and surface tention characteristics.

V TRANSPORT SYSTEM

One can see from examination of the foregoing definitions and the differences in oils and waters that there are many variables affecting the nature and stability of the distribution of oil particles in water. Of these variables, turbulence level is the most easily controlled. Considering that one must transport the oily water from some source to an oil/water separator, and that the level of turbulence of the oil/water combination affects the quantity of small and difficult-to-separate oil particles in the oil particle distribution, it becomes clear that one must minimize turbulence in the transport system.

Pump Type

To minimize turbulence, the choice of pump type becomes very important. Low turbulence in a pump, according to Shackleton, et al. (Ref. 1), is achieved best in a configuration with a low discharge pressure, low speed, ample internal dimensions and having smooth flow paths free from obstructions (such as valves in a diaphram pump). The pump configurations best meeting these criteria are all positive displacement type and are, in order of increasing turbulence level produced, double vane, triple screw, single vane and rotary gear. Shackleton recommends that these pump types be derated 50% for use in pumping oily water combinations. The criteria for rating the above pumps were that they all produce less than 5% oil (Bunker "C"; about equal to a #5 fuel oil), droplets less than 0.01 inch (0.25mm) diameter.

Other pumps tested, and rated in order of decreasing suitability for separator use were: reciprocating and hypocyclodial: not satisfactory; modifications may improve efficiencies to "satisfactory level" --diaphram, disc, and shoe, centrifugal, flexible vane: all "unsatisfactory".

Piping and Valving

The considerations of low turbulence within a pump apply equally well to the piping and valving required to complete the transport system of the oily water. Piping should be of as large a diameter as practical; bends should be kept to a minimum and be of long radius design. Valves should be of a full bore design; used in the fully open or fully closed position when passing only water, and not used for flow regulation.

VI OIL/WATER SEPARATORS

Now that the oily water has been transported in the optimum manner to the separator we can consider the various ways of removing the particles from the water. Principal methods of separation can be classified as physical, chemical or biological treatment.

Physical Treatment consists of flotation coalescence, filtration and unusual physical separation methods.

Flotation

Consider the forces acting upon an oil particle suspended in water. The particle has a net mass equal to the density differential between the particle and the surrounding fluid. Accelerations present are those of gravity and viscous drag of the continuous fluid against the particle. The resulting forces are those of buoyancy, which is dependent principally on the volume of the particle, and viscous drag, which is principally dependent on the velocity of the water relative to the oil, and the surface area and shape of the particle. Assuming spherical particles, the surface area to volume ratio of the particle gives a qualitative indication of the relative magnitude of the two principal forces:

$$SA = \pi D^2$$

$$V = \frac{\pi D^3}{6}$$

$$\frac{SA}{V} = \frac{6}{D}$$

One can see from the above that as the diameter of a particle decreases, a surface area effect relative to a volume effect will become more pronounced. More precise statements of the relative effects of buoyancy and drag are found in the three flotation laws which relate particle size, relative velocity and other parameters to the rise velocity under zero net flow conditions. Stokes law applies for streamline flow, for particle size from 0-0.25" in diameter; Newton's law applies for turbulent flow, for particles 0.35" diameter and larger; and an intermediate law applies for intermediate particle sizes and flow conditions. The conditions associated with most oil/water separators can be represented by the Stokes and/or intermediate laws.

For a given oil in a given water, a separator can be designed to achieve maximum practical utilization of the parameters which affect the rise of oil particles.

We wish to achieve:

Increased temperature of water affects mainly water viscosity; reduces drag on particles; greater percentage change at low (60 - 80°F) temperature.

Minimum turbulence such that horizontal drag on the particle and particle shear are minimized. (API separator designed for laminar flow)

Maximum density differential (air flotation reduces net density of particle when air bubble attaches itself to particle)

Maximum rise time afforded (flow rate and volume relationship; API separator designed for rise of 15μ particles)

Minimum rise distance for particle (parallel plate interceptor)

Maximum acceleration acting on the particle to move the particle to a designed area of the separator (centrifuge, hydrocyclone, open-center pump)

While flotation is a satisfactory technique for the separation of the larger oil particles in a distribution, the particles smaller than 0.25 mm in diameter are usually subjected to excessive horizontal drag and insufficient rise time for the given rise distance in a separator of practical configuration. Insufficient density differential can also be troublesome.

Coalescers

Coalescence can be defined as the generation of a concentrated oil volume from a dispersed oil volume by physically uniting the interfaces of the small particles with each other and with the concentrated volume of oil. A common means of achieving coalescence is to place a network of oleophilic and hydrophobic material in the flow path of the oil particles. The particles adhere to the oleophilic surface, which eventually becomes coated with a film of oil, which in turn "encourages" the coalescence of smaller oil particles coming in contact with the coated surface. Most coalescer packing is a net, a screen, or a porous or fibrous woven mesh which has a high ratio of surface area to volume. The tendency of the particles to remain suspended as particles is a function of the particle size, the quantity and type of surfactants present, all of which affect the oil-water interfacial tension, and the electrostatic charge characteristics of the particles and the surrounding water. In some coalescers, heat and/or a demulsifying agent is added to lower the interfacial tension between oil and water in order to achieve better separation. Coalescer design usually involves continuous or intermittant withdrawl of the collected oil.

The Environmental Protection Agency is funding basic research into coalescing phenomena in order to more clearly define the mechanisms involved.

Filtration

Filtration, as applied to oil/water separation, is closely related to coalescing and involves straining, coagulation, localized sedimentation, adhesion, cohesion, viscosity and interfacial tension effects. Many different materials have been used to remove relatively small amounts of oil from water, most of which depend on oleophilic properties to retain oil as an adsorbed film. Mesh filters, pebble and sand beds, sponges and felts are some examples. Filters are usually backwashed for cleaning, or employed as a disposable cartridge for a final "polishing" step in a separation system. Principal difficulties with filters are large pressure drops, dirt and scale interference, and backwashing problems, particularly with viscous oils. (Reg. 2)

Unusual Physical Separation Techniques

For extremely fine dispersions and emulsions which defy separation by other physical means, unusual physical separation methods can be applied. Magnetic, electric, and sonic energy in combination with membranes for selective diffusion and exotic materials for various other specific purposes have been used in a wide variety of combinations and configurations in attempts to solve specific emulsion breaking problems. Dialysis, electrodialysis, electrophoresis, magnetoelectrophoresis and corona discharge are a few of the methods which have been applied. The apparatus and energy levels required to achieve separation of the smallest and most stable oil particles by unusual physical techniques made these methods prohibitively expensive for most practical large scale applications.

Chemical Treatment

Difficult emulsions can be broken by addition of chemicals formulated for a specific application. These emulsion-breakers usually require storage, pumping, and piping systems to be built of special materials and may present a handling problem. Further, the chemicals may be pollutants in themselves or have synergistic effects with the oil or water in ways which may not be readily predictable.

Biological Treatment

Oil may be degraded by microbiological activity into cell matter or carbon dioxide and water, depending upon the available oxygen concentration. The rate of the degradation depends upon the type of hydrocarbons present, the temperature, and the concentration of organic nutrients (Nitrogen and Phosphorous) present. "The long-term rate of decomposition of oil by microbial processes would be limited by oxygen availability to approximately 13 to 20 pounds of hydrocarbons per acre-day (approximately 0.0001 inch of oil from a surface layer per day)". (Ref.3) In most cases, biological treatment of an oily waste water is too slow to be practical.

VII TYPICAL APPLICATIONS, CONSTRAINTS, PROBLEMS

A Oil Spill Control

Most oil spill skimming devices are designed to empty, under pressure of vacuum, into settling chambers where most of the free oil floats out. These chambers are often open to the sea or spill area such that the clarified water is displaced out as the oil fills the chamber.

The Environmental Protection Agency has funded three separator developments specifically for oil spill cleanup application: a centrifuge, a modified hydrocyclone, and an open center pump. Of the three, the open center pump appears to offer the most promise of meeting the requirements of an oil spill cleanup separator: simplicity, reliability and high processing capability per unit of weight and volume.

B Bilge and Ballast Applications

There has not been a great amount of effort devoted to development of separator designs specifically for bilge applications. As mentioned above, the bilge oils usually contain a high quantity of surfactants, which can cause difficulties with coalescers. The Naval Ship Engineering Center at Annapolis, Maryland is presently undertaking research to improve bilge and ballast water separators for Naval vessels. The principals involved are flotation and coalescence.

Dry cargo vessel ballast water treatment has received considerable attention, particularly from the Maritime Administration, who has funded and is funding considerable research in that area. Most commerical ballast water treatment facilities for merchant vessels rely on flotation followed in some cases by a coalescer or filter, or both. According to a study done for MARAD by the Permutit Company (Ref. 2), Bunker "C" oil available on the West Coast and at Hawaii is sometimes heavier than water, rendering flotation type separators useless in those areas. Further, scale, rust particles, and other matter present in ballast water cause difficulties with present coalescer designs.

Tanker ballast water treatment poses difficult problems. While the oil product is usually crude with a specific gravity less than 1.0, contamination of ballast water with particulate matter is still a problem to coalescer designs. Separators required for tanker ballast treatment could be used in two configurations:

With Load on Top a separator could be used to clarify the water in the slop tank as it is being discharged overboard; this is the most reasonable on-board application. However, with the Load on Top, corona discharge from the tank cleaning nozzle through the oil vapor in the tank being cleaned can cause an explosion, therefore, there is a desire on the part of the tanker industry to replace Load on Top with another form of ballast water treatment.

Shore-Based Deballasting is an alternate technique. There is no need for Load on Top, and space requirements are not as stringent as aboard the tanker. The entire contents of the ballast tanks may be offloaded into shore-based tankage while the tanker is taking on a new load of crude. After settling time in a large tank, the remaining oil-in-water combination may be treated by conventional API separators or coalescers or other treatment facilities.

Industrial Wastewater Treatment

Commerical separators for industrial applications vary in size and sophistication from an empty tank for free-oil flotation to heater-treaters for offshore oil drilling applications. The API separator is a standard design for the oily industry, and has been proven effective for many applications. (Ref. 4) Many industrial oil/water separation facilities involved staged oil removal: free oil flotation followed by coalescing with or without chemical addition, followed by dissolved air flotation. Most industrial wastewater streams could have oil removal to a level of a few parts per million, if the industry involved is willing to own and operate the required apparatus.

VIII SUMMARY

Oil/water separator design depends on the nature of the oil, the nature of the water, and the nature of the oil in the water. The oily water transport system, i.e., pump, piping and valves, can have considerable effect on the particle size distribution of the oil in the water. Oil can be removed from water by physical, chemical or biological means. The most common physical treatment techniques utilize flotation, coalescence or filtration. Small oil particles (usually less than 0.25 mm) resist flotation due to viscous drag of the water. Surfactants alter the surface tension of the oil particles, and reduce the coalescibility of the oil. Filters have high pressure drops and can become clogged with particulate matter. Chemicals may be added to oil/water combinations to break emulsions, however, the chemicals may be pollutants in themselves. Microbiological treatment can break oil down into carbon dioxide and water, under the right conditions, but the rate of decomposition is slow. Within the U.S. Government, research and developmnet for the improvement of oil/water separators is being conducted by the U.S. Naval Ship Engineering Center, (bilge and ballast applications for Naval vessels), the U.S. Maritime Administration (dry cargo and tanker vessel ballast water treatment), and the Environmental Protection Agency (oil spill control, basic research into coalescing).

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CLEANUP OF OIL-POLLUTED BEACHES

I INTRODUCTION

National and international publicity given to Torrey Canyon and Santa Barbara incidents have led to a public outcry to stop the oil pollution of our national shorelines.

II QUESTIONS ON BEACH CLEANUP

The question is often asked, "How do you clean an oil polluted beach?" The answer to this question is relative. What is the composition of the beach? Is it fine grain sand; is it coarse sand; is it pebble or shingle beach? What type of oil pollution has fouled the beach? Was it a #2 oil, #6 or a crude oil? How deep is the oil penetration? What is the temperature and the season? Where is the beach located? Does it have access roads? Can it be reached or traversed by wheeled vehicles or can it only accomodate tracked vehicles? Before we can even begin to answer a question on beach cleanup, we must know as many background facts as possible.

III CLEANUP METHODS

A It has often been said that nature is the best cleaning agent in the world. This is especially true of rocky shores and stone beaches. But if anyone reports that nature removed oil from a sand beach - dig a little deeper - literally. What nature cannot remove, it covers up. Wind blown sand and the seasonal movement of beaches have a tendency to cover man's mistakes.

B The most elementary method of beach cleanup is with the use of rakes, shovels and manpower. If the penetration of oil into the sand is less than two inches and the oil is not too fluid, the oil can be raked into windrows of approximately one foot and picked up with shovels to be placed into a front loader or dump truck. If the oil is not sufficiently weathered to be viscous, it can be made more workable through the application of a cold water spray from a garden hose or a fire hose.

C If the pollution damage to the beach is much more extensive, then mechanical equipment must be used. Through research, it has been determined that a Motorized Elevating Scraper used in tandem with a motorized scraper, are the best mechanical equipment to be used in beach restoration. The combined uses of these vehicles provide the most rapid means of beach restoration and in addition their use results in the removal of the least amount of excess beach material. Before allowing mechanical equipment on the beach, the operators of these vehicles must be cautioned on the amount of beach sand to be removed.

IV PREVENTION

A It is much easier to clean up a beach if the oil is stopped at or near the water line. An effective method of protecting a high-use beach from the onslaught of oil pollution is to throw up a sand berm approximately three feet high. This can be accomplished with the use of earth moving equipment or, if necessary, by hand labor. The artificial berm should be placed along the high water mark, to protect the dry sand above the intertidal zone. If the surf is strong or very active, or if there is an abnormally high tide, the artificial berm will be destroyed. Sufficient to say that the artificial berm will only prove effective in a mild surf and calm weather.

B Should sufficient time exist between the notification of an oil spill and its reaching the shore face, one method of alleviating the damage to the beach is the extensive use of straw, either alone, or used in conjunction with the commercial "sorbents."

Straw, which has a natural absorptive capacity for oil, will adsorb between four and ten times its own weight in oil. To be most effective, the straw should be laid along the low-water mark and as the tide and oil move up the beach, the straw should be worked into the oil, either through natural wave action or mechanical methods.

C If the oil is still washing ashore a series of deep pits can be gouged out of the sand at the water's edge to allow the oil to build up sufficient thickness to permit removal by vacuum tank truck.

V CHEMICALS

A We firmly believe that the use of dispersants, emulsifiers and other chemicals is entirely unjustified in the cleanup of oil polluted beaches. In both the Torrey Canyon and Ocean Eagle incidents, it was noted that the use of chemicals on sand caused the sand to become "quick", making it difficult to walk on and leaving a disagreeable odor in the treated sand. (However, other reports cite this same "quicksand" with oil alone. As the literature on this subject is very vague, further research by the government and private industry seems indicated.)

B In oil penetration tests conducted at Sandy Hook, N.J., it was concluded that various types of persistent oil alone penetrated no more than two inches into the sand while oil mixed with chemicals (dispersants, emulsifiers, etc.) caused penetration of the mixture into the sand at least three times the depth of the untreated oil.

C Application of chemicals to an oil soaked beach and subsequent hosing down of the mixture with sea water, the sand appeared cleansed of oil. However, further investigation revealed that this observation was deceptive, as the oil and chemical mixture was found between four and twelve inches, in irregular bands, below the surface of the sand.

VI BURNING

Many attempts have been made to burn oil on the shore face. Through an extensive literature search and personal observation it is concluded that the burning of oil "in situ" on a contaminated beach is not very practicable. It has been tried with commercial burning agents, flame throwers, "oxygen tiles" and various mixtures of kerosene and gasoline, but all have met with no success. Small, "fresh" pools of neat crudes or light oil can be burned successfully if their lighter ends have not evaporated, but this is a patchy operation at best and is not recommended for cleanup of massive spills.

VII CLEANUP OF LIGHT OILS

A Sometimes a "high-use" beach becomes stained with a light oil such as a #2 fuel. This becomes a problem because of instant and deep penetration. The only really effective method of cleansing this type of pollution is to expose as much of the contaminated beach sand to the sunlight and wind as possible. This can be done effectively by the use of a harrowing plow or beach cleaning machines, which are used to remove trash from beaches.

Number two fuel, in contrast to #6 or Bunker "C" fuel oil, contains a relative high amount of light ends. If these light ends are exposed to evaporation through wind and weather, they will dissipate rather rapidly.

B To accelerate the evaporation and dissipation of #2 fuel from the beaches, a mat of straw should be laid on the beach, at least one inch thick. A disk-harrow should then be used to work the straw down into the sand column so the straw can absorb as much of the oil as possible. A beach cleaning machine should then be used to retrieve the oil soaked straw. The beach should then be harrowed or mechanically raked to hasten the dissipation of the remaining oil trapped in the sub-surface of the sand.

This outline was prepared by H. J. Lamp'l, Oil Spills Coordinator, Office of Water Programs, Edison Water Quality Laboratory, Edison, N.J.

LEGISLATION AFFECTING OIL

I INTRODUCTION

On April 3, 1970, the President of the United States signed into law the "Water Quality Improvement Act of 1970." This is the latest law enacted to fight oil pollution. It is one of many laws passed to combat oil spills since the first oil well was drilled in the United States in Titusville, Pennsylvania on August 27, 1859.

II PRIOR LAWS

A "Refuse Act"

U.S. Code, Title 33, Section 407 Law enacted by Congress in March 1899. Superseded prior act of September 19, 1890. This act not only forbids discharge of refuse into the navigable waters (or tributaries of navigable waters, it also forbids the placing of refuse on the banks of a navigable water or tributaries thereof) where such refuse shall be liable to be washed into the navigable water. The penalty under this section is covered by Section 411 and provides for a fine not exceeding $2,500 nor less than $500, or by imprisonment (in the case of a natural person) for not less than thirty days nor more than one year, or by both such fine and imprisonment, in the discretion of the court, one-half of such fine to be paid to the person or persons giving information which shall lead to conviction. (A Federal Court of Appeals held in 1936 that oil was refuse matter within the meaning of this section (La Merced, 84 F.2d 444). The U.S. Supreme Court held in 1966 that gasoline was refuse matter within the meaning of this section (U.S. v Standard Oil Co., 384 U.S. 224). The U.S. Supreme Court has also held in 1960 that injunctive as well as criminal relief is available under this section (U.S. v Republic Steel Corp. 362 U.S. 482).

B U.S. Code Title 33, Section 441 Law enacted by Congress on June 29, 1888. Superseded prior act of August 5, 1886. This act is known as "The Supervisor of New York Harbor Act", but it also applies to the harbors of Baltimore, Maryland and Norfolk, Virginia. This act provides, upon conviction (for discharging any matter of any kind into the harbors that a person shall be punished by fine or imprisonment, or both,)such fine to be not less than $250 nor more than $2,500, and the imprisonment to be not less than thirty days nor more than one year, either or both united, as the judge before whom conviction is obtained shall decide, one half of said fine to be paid to the person or persons giving information which shall lead to conviction of this misdemeanor. [A Federal District Court in 1928 said that waste fuel oil discharges are prohibited by this section (The Albanis, 30 F.2d 727)].

C Congress enacted the "Oil Pollution Act of 1924" which provided for fines up to $2,500 for discharges of oil from vessels into coastal navigable waters. This Act was repealed by the Water Quality Improvement Act of 1970.

D Outer Continental Shelf Lands Act of 1953 U.S. Code Title 43, (sections 1331-1343). This act authorizes the Secretary of the Interior to issue on a competitive basis leases for oil and gas, sulphur and other minerals in submerged lands or the Outer Continental Shelf. Subject to the supervisory authority of the Secretary and the Director of the Geological Survey, drilling and production operations including pollution prevention are controlled through the issuance of regulations and orders.

E U.S. Code Title 33, Section 1001 enacted by Congress in 1961 and amended in 1966. The Oil Pollution Act of 1961 implemented the provisions of the International Convention for the Prevention of the Pollution of the Sea by Oil, 1954. To prevent discharge or escape of oil or oily mixture by sea-going vessels, (NOTE: Oily mixture is defined as a mixture with an oil content of 100 ppm or more). Vessels required to maintain Oil Record Book. Prohibited zone: All seas within 50 miles from nearest land (baseline from which territorial sea is established) and other areas as defined in the convention. Amendments to this law were adopted by International Convention in 1969 but have not yet been ratified by U.S.

F "Clean Waters Restoration Act of 1966. This act amended the Oil Pollution Act of 1924. This was not a strong law because to obtain a conviction for a discharge of oil from a vessel you had to prove "willful spilling", or gross negligence. This act was repealed by the Water Quality Improvement Act of 1970.

III WATER QUALITY IMPROVEMENT ACT OF 1970. PUBLIC LAW 91-224

A Section II Control of Pollution by Oil

1 Quantities of oil which may be discharged

Title 18, Part 610 of theCode of Federal Regulations gives this definition of oil which may not be discharged: Include discharge which:

a Violate applicable water quality standards, or

b Cause a film or sheen upon or discoloration of the water or adjoining shorelines or causes a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

2 Notification (Penalty)

Title 33, Part 153 of the Code of Federal Regulations states: Subsection 11(b) (4) of the Act requires that any person in charge of a vessel or of an onshore or offshore facility, as soon as he has knowledge of any discharge of oil in harmful quantities from such vessel or facility into or upon the waters designated by the Act or the adjoining shorelines, shall immediately notify the appropriate agency of the United States Government of such discharge. The "appropriate agency" is listed as follows:

a The Commanding Officer or officer in charge of any Coast Guard unit in the vicinity of the discharge;

b The Commander of the Coast Guard District in which the discharge occurs.

c The Federal official designated in the Regional Oil and Hazardous Materials Pollution Contingency Plan as the On-Scene Commander (OSC) for spill response purposes.

If the above officials cannot for some reason be notified, then notification should be given to:

a The Commandant, U.S. Coast Guard

b Regional Director, EPA Water Quality Office, for the region in which the discharge occurs

The penalty for failure to notify one of the foregoing immediately is up to $10,000 or imprisonment for up to one year.

3 Knowingly discharging oil

Section 11 (b) (5) of the Act provides $10,000 fine for knowingly discharging oil into the navigable waters. This is a civil penalty and shall be assessed by the Secretary of the department in which the Coast Guard is operating. Each violation is a separate offense.

4 Areas affected

The discharge of oil into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone in harmful quantities, as determined by the President, is prohibited, except (A) in the case of such discharges into the waters of the contiguous zone, where permitted under Article IV of the International Convention for the Prevention of the Pollution of the Sea by Oil, 1954, as amended and (B) where permitted in quantities and at times and locations or under such circumstances or conditions as the President may, by regulation, determine not to be harmful. Title 33, Part 153 of the Code of Federal Regulations provides that discharges of oil from properly functioning vessel engines are not deemed to be harmful.

5 Removal of oil from water and shoreline

Whenever any oil is discharged, into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone, the President is authorized to act to remove or arrange for the removal of such oil at any time, unless he determines such removal will be done properly by the owner or operator of the vessel, onshore facility, or offshore facility from which the discharge occurs.

6 National contingency plan

a Section 11 (c) (2) of the Act calls for the preparation of a National Contingency Plan. The National Oil and Hazardous Materials Pollution Contingency Plan has been established and is operative. This Plan provides for efficient, coordinated, and effective action to minimize damage from oil discharges including containment, disposal and removal of oil.

b As part of the Plan, Section 11 (c) (2) (C) of the Act, requires "establishment or designation of a strike force consisting of personnel who shall be trained, prepared, and available to provide necessary services to carry out the Plan, including the establishment at major ports, to be determined by the President, of emergency task forces of trained personnel, adequate oil pollution control equipment and material and a detailed oil pollution prevention and removal plan."

c Dispersants and other chemicals

As required in section 11 (c) (2) (G) of the Act, the Plan provides that dispersants shall not be used:

1) On any distillate fuel

2) On any spill of oil less than 200 barrels in quantity

3) On any shoreline

4) In any waters less than 100 feet deep

5) In any waters containing major populations, or breeding or passage areas for species of fish or marine life which may be damaged or rendered commercially less marketable by exposure to dispersant or dispersed oil.

6) In any waters where winds and/or currents are of such velocity and directions that dispersed oil mixtures would likely, in the judgment of EPA, be carried to shore areas within 24 hours.

7) In any waters where such use may affect surface water supplies.

d Sinking agents

Sinking agents may be used only in marine waters exceeding 100 meters in depth where currents are not predominately on-shore, and only if other control methods are judged by EPA to be inadequate or not feasible.

7 Removal or destruction of vessel

When as a result of a marine disaster, there is a discharge, or an imminent discharge, or large quantities of oil from a vessel causing a substantial threat of danger, the United States may (a) coordinate and direct all public and private efforts directed at the removal or elimination of such threat; and (b) summarily remove, and, if necessary, destroy such vessel by whatever means are available without regard to any provisions of law governing the employment of personnel or the expenditure of appropriated funds.

8 Threat from facilities

When there is an imminent and substantial threat to the public health or welfare from an actual or threatened discharge of oil from an onshore or offshore facility, judicial relief can be sought to abate the threat.

9 Cost of cleanup

a Vessel

An owner or operator of a vessel from which oil is spilled, shall be liable to the United States Government in an amount not to exceed $100 per gross ton of such vessel of $14, 000, 000, whichever is lesser, except where it can be proven that the discharge was caused solely by (A) an act of God (B) an act of war (C) negligence on the part of the U.S. Government or (D) an act or omission of a third party without regard to whether such act or omission was or was not negligent. Where the United States can show that such discharge was the result of negligence or willful misconduct within the privity and knowledge of the owner, such owner or operator shall be liable to the United States Government for the full amount of such cost. Such cost shall constitute a maritime lien on such vessel which may be recovered by an action in rem in the district court of the United States for any district within which any vessel may be found.

b Offshore facility

The owner or operator of offshore facility from which oil is spilled, shall be liable to the United States Government for the actual cost incurred for the removal of such oil by the United States Government in an amount not to exceed $8, 000, 000, except where it can be proven that the discharge was caused solely by (A) an act of God (B) an act of war (C) negligence on the part of the U.S. Government or (D) an act or omission of a third party without regard to whether such act or omission was or was not negligent. Where the United States can show that such discharge was the result of willful negligence or willful misconduct within the privity and knowledge of the owner, such owner or operator shall be liable to the United States Government for the full amount of such cost. The United States Government may bring an action against the owner or operator of such a facility in any court of competent jurisdiction to recover such cost.

c Onshore facility

The owner or operator from which oil is spilled shall be liable to the United States Government for the actual cost incurred for the removal of such oil by the United States Government in an amount not to exceed $8, 000, 000, except where it can be proven that the discharge was caused by (A) an act of God (B) an act of war (C) negligence on the part of the U.S. Government, or (D) an act or omission of a third party without regard to whether such act or omission was or was not negligent. Where the United States can show that such discharge was the result of willful negligence or willful misconduct within the privity and knowledge of the owner, such owner or operator shall be liable to the United States Government for the full amount of such cost. The United States may bring an action against the owner or operator of such facility in any court of competent jurisdiction to recover such cost.

10 Regulations

Consistent with the National Contingency Plan, regulations are to be issued establishing (A) methods and procedures for removal of discharged oil (B) criteria for local and regional contingency plans (C) procedures, methods and requirements for equipment to prevent discharges of oil, and (D) procedures for inspection of vessels carrying oil. An administrative civil penalty of up to $5000 can be assessed for violation of these regulations.

11 Revolving fund

There is authorized to be appropriated a revolving fund to be established by the Treasury not to exceed $35,000,000 to carry out the provision of cleanup as stated by the Act. Any other funds received by the United States under this Act shall also be deposited in said fund for such purposes. All sums appropriated to, or deposited in, said fund shall remain available until expended.

12 Evidence of financial responsibility

This section provides that any vessel over three hundred gross tons, including any barge of equivalent size, using any port or place in the United States for any purpose shall establish and maintain under regulations to be prescribed from time to time by the President, evidence of financial responsibility of $100 per gross ton, or $14,000,000 whichever is the lesser, to meet the liability to the United States which such vessel could be subjected under this law. In cases where an owner or operator owns, operates, or charters more than one such vessel, financial responsibility need only be established to meet the maximum liability to which the largest of such vessels could be subjected. Financial responsibility may be established by any one of, or a combination of, the following methods acceptable to the President: (A) evidence of insurance; (B) surety bond; (C) qualification as a self-insurer; or (D) other evidence of financial responsibility. Any bond filed shall be issued by a bonding company authorized to do business in the United States.

13 This section provides that nothing in the section shall be construed as preempting any State or political subdivision thereof from imposing any requirement or liability with respect to the discharge of oil into any waters within such State.

B Executive Order 11548

This Executive Order, dated July 20, 1970, assigned the various responsibilities and authorities for implementing the oil pollution provisions of Section 11 to EPA, Department of Transportation (Coast Guard), Federal Maritime Commission, and Council on Environmental Quality. The Coast Guard is responsible for cleanup and enforcement in coastal and contiguous zone waters, high seas, Great Lakes waters. EPA is responsible for inland waters.

This outline was prepared by J. William Geise, Jr., Program Advisor (Legal), Division of Oil & Hazardous Materials, Washington, D.C. and Howard Lamp'l, Contingency Plans Officer, Edison Water Quality Laboratory, EPA, Edison, NJ 08817.

NATIONAL AND REGIONAL CONTINGENCY PLANS

I INTRODUCTION

The Federal Water Pollution Control Act, as ammended (P.L. 91-224, 84 Stat. 93, 1970) directed the preparation of a National Contingency Plan for Oil and Hazardous Materials. This plan, published in the Federal Register on June 2, 1970, superseded the National Multiagency Oil and Hazardous Materials Contingency Plan which was approved in September, 1968.

II PURPOSE

The Plan provides for a pattern of coordinated and integrated response to major pollution incidents by departments and agencies of the Federal government. It establishes a national response team and provides guidelines for the establishment of regional contingency plans and response teams. The plan promotes the coordination and direction of Federal, State and local response systems and encourages the development of local government and private capabilities to handle pollution spills.

III OBJECTIVES

The objectives of the plan are to develop effective systems for discovering and reporting the existence of a pollution spill, promptly instituting measures to restrict the further spread of the pollutant, to assure that the public health, welfare and national resources are provided adequate protection, application of techniques to cleanup and dispose of the collected pollutants, and institution of action to recover cleanup and effective enforcement of existing Federal statutes.

IV SCOPE

The plan is effective for all United States navigable waters including inland rivers, the Great Lakes, coastal territorial waters, and the contiguous zone and high seas beyond this zone where there exists a threat to United States waters, shoreface or shelf bottom.

V PARTICIPATING AGENCIES

Each of the primary Federal agencies has responsibilities established by statute, Executive Order or Presidential Directive, which may bear on the Federal response to a pollution spill. This plan intends to promote the expeditious and harmonious discharge of these responsibilities through the recognition of authority for action by those agencies having the most appropriate capability to act in each specific situation.

The primary Federal Agencies are the Environmental Protection Agency, the Departments of Transportation, Defense, Interior, and Health, Education and Welfare, and the Office of Emergency Preparedness.

VI ORGANIZATION

The plan provides for a National Inter-Agency Committee (NIC) which is the principal instrumentality for plans and policies of the Federal response to pollution emergencies.

At the Washington level, the plan establishes a National Response Team (NRT) consisting of representatives from the primary agencies. This team acts as an emergency response team to be activated in the event of a pollution spill involving oil or hazardous material which: (a) exceeds the response capability of the region in which it occurs, (b) transects regional boundaries, or (c) involves national security or major hazard to substantial numbers of persons or nationally significant amounts of property. A National Response Center (NRC) in Washington, D.C. is the headquarters site for activities relative to pollution spills.

There are established throughout the United States, Regional Response Teams (RRT) that perform functions within the regions similar to that performed by the National Response Team on the national level. Regional Response Centers (RRC), similar to the NRC, are located in each of the pre-designated regions.

The plan further provides that in each region, there will be established On-Scene-Commanders (OSC). The On-Scene-Commander is the single executive agent pre-designated by regional plan to coordinate and direct such pollution control activities in each area of the region. The first responsible Federal representative to arrive on-scene automatically becomes the on-scene commander until he is officially relieved by the pre-designated on-scene commander.

VII DELEGATION OF RESPONSIBILITY

The U.S. Coast Guard is to provide for On-Scene-Commanders in areas where they have assigned responsibility, which includes the high seas, coastal and contiguous zone waters, coastal and Great Lakes ports and harbors. The Environmental Protection Agency will furnish or provide for On-Scene-Commanders in other areas.

VIII FEDERAL RESPONSE OPERATION

The actions taken to respond to a spill or pollution incident can be separated into five relatively distinct classes or phases. For descriptive purposes, these are:

Phase I. Discovery and Notification

Phase II. Containment and Countermeasures

Phase III. Cleanup and Disposal

Phase IV. Restoration

Phase V. Recovery of Damages and Enforcement

It must be recognized that elements of any one phase may take place concurrently with one or more other phases.

IX REGIONAL CONTINGENCY PLANS

Separate regional plans are to be developed by the Environmental Protection Agency and the United States Coast Guard for the respective areas of responsibility within each region. All regional plans are to be oriented in accordance with the ten (10) standard Federal administration regions.

All regional contingency plans will contain, as a minimum the following items:

A A definition of the area covered including the points of change in jurisdiction between Environmental Protection Agency and U.S. Coast Guard.

B A notification and reporting system beginning with the initial discovery of a spill.

C Names, addresses and phone numbers of all pertinent Federal, State, local and industry personnel involved in the reporting system.

D A listing of predesignated On-Scene-Commanders and Regional Response Centers.

E Listing of resources and equipment available in the regional area with names, addresses and phone numbers.

F Categorization of water areas by use to establish predetermined cleanup priorities.

This outline was prepared by A.W. Bromberg, Chief, Operations Branch, OWP, EPA, Edison Water Quality Laboratory, Edison, N.J.

FUNCTIONS, RESPONSIBILITIES AND ROLE OF THE ON-SCENE-COMMANDER

I INTRODUCTION

A You may be designated as the On-Scene-Commander during the next major oil spill that takes place in your area of responsibility. Are your prepared?

II BACKGROUND

A What are the qualifications of a good On-Scene-Commander? He should be a well trained individual, whose background includes oil pollution research, experience with a number of actual spills of different types of oil, a knowledge of the shipping industry and a good background in law and existing oil pollution legislation.

B Basically, the On-Scene-Commander is a decision making "machine", working at least twelve hours per day over a long period of time. To make these decisions in an intelligent manner, he must have the basic background to support his decisions. If a wrong decision is made, the results could range from embarrassment to the Federal Government, to injury or death to substantial numbers of persons.

C A good On-Scene-Commander must have many attributes. First of all, he must have good managerial ability. From utter chaos, he must organize a small army of men and equipment to remove the oil from the water and shoreface. He must be a statistician for he has to provide and direct great amounts of money, equipment services and manpower. He must have a sense of humor, because no matter how well the cleanup is going, some elements of the public are going to cry for instant and dramatic cleanup. And finally, he must have the ability to walk a tenuous tightrope, to try to please as many of the public, who have been injured by the spill, as possible. For instance: the sunbathers and swimmers want the beaches and surf cleaned at once; the bird lovers want the birds protected at all cost; the vessel owner wants his vessel cleaned of all traces of oil pollution; shore-front property owners want their homes protected and cleaned; the commercial and sports fishermen would rather have the oil come ashore than have it do any damage to marine life; and finally, the oil and shipping industry want the channels kept open at all cost.

III ORGANIZATION

A Staff

Every On-Scene-Commander should be backed up with a fully trained staff. This staff should include, but is not limited to: a public information officer, to handle the countless calls and inquiries from the news media; a stenographer, to keep a running account of all business transacted during any given day; a contracting officer, to handle the myriad details for the hiring of and negotiations with various contractors, purchase request and the recording and handling of petty cash funds. He should also have on his staff, technicians to supervise and "straw-boss" the various contractors and to do general field work during the life of the spill. These technicians should be well versed in oil pollution work. Finally, the On-Scene-Commander should have available to him legal council for consultation when the need arises; fully trained chemist, biologist and engineers who have a good background in oil pollution work.

B Quarters and Equipment

The On-Scene-Commander and his staff should have a suitable headquarters in which to work. Ideally, a Coast Guard Station would provide a suitable headquarters if it were near the scene of the spill. If not, then other quarters must be found. These quarters could be a suite of motel or hotel rooms; a house trailer; a mobile laboratory, as found in the EPA, Water Quality Offices, or a private beach house.

The operations headquarters should be equipped with the following items: wall charts, maps, at least eight telephones, desks, chairs, writing equipment, typewriters and if possible, a teletypewriter. One of the most important items of equipment in the headquarters, is the Commander's Log. The Commander's Log, a permanent bound book, should be maintained from the inception of the spill until the case is closed out. In it, there should be recorded, chronologically, a reference to all telephone calls received, meetings held, orders issued, events taking place, personnel changes, visitors received, overflights made, etc. This Log can be an invaluable record of the spill to be later used in court or congressional hearing.

C Communications

Whenever the On-Scene-Commander and his staff are housed, the first order of business upon arrival is to order phones. At least eight phones should be installed. One of the eight telephone numbers should not be given out for general use, but should be reserved and made known to only a few selected individuals who may have to communicate with the On-Scene-Commander on urgent matters.

It is imperative that the On-Scene-Commander have communications with the contractors in the field and with his observers. Small, portable hand-held radios with sufficient range would be the ideal answer. If radio communications are not available, there is another system which can be found in most large cities. This system is called "People Beepers". It is a small, belt-clip-on radio receiver with a range of approximately twenty-five miles. To get a contractor or observer in the field, the On-Scene-Commander dials a specified number and asks the operator to have No. A-16 call headquarters. The operator in turn activates a "beeper" on the radio receiver No. A-16 and transmits the message. The holder of receiver No. A-16 in turn calls the On-Scene-Commander by telephone and communications are established. This system can be rented for a nominal fee.

Communications between air observers and headquarters is a necessity and observation and work vessels should also be able to contact the field headquarters.

IV RELATIONS WITH OTHER ORGANIZATIONS

A Federal

1 Environmental Protection Agency

2 U.S. Coast Guard

3 U.S. Army Corps of Engineers

4 U.S. Health, Education and Welfare

5 Office of Emergency Preparedness

These are the basic Federal Agencies concerned with a major oil spill. However, many other Federal Agencies may be called on to furnish help during the life of the emergency; they may include, but are not limited to, the following:

a U.S. Air Force

b U.S. Navy

c U.S. Army

d General Accounting Office

e General Services Administration

B States

Individual states are encouraged to make commitments to the cleanup of major oil spills. If the state decides that it wants to take complete charge of the spill, it is the policy of the Federal government to agree and then monitor the situation. The problem here lies in the fact that very few states have the funds committed by legislation to become involved in a major oil spill cleanup.

C Interstate Agencies

Interstate agencies too, are encouraged to make commitments to the cleanup of major oil spills. Interstate agencies can also take complete charge of a major oil spill, but again, the funding limitations applies to these agencies as well as to the individual states.

D Local Government

Local governments will rarely have the funds to combat a major oil spill. However, they can be an invaluable source of manpower and equipment.

E Academic Communities

The academic communities throughout the country can usually be counted on to furnish information and advice on the local environment, during a major spill. Quite often, you will find that these institutes have previously made extensive biological studies of local areas and this can be of invaluable help in comparison with post spill biological surveys.

V FINANCING

A All cost of cleanup should be borne by the polluter. In most cases, the major oil and shipping companies will shoulder this responsibility without question. If the company agrees to finance the cost of cleanup, they will probably want to take charge of the operations. This is agreeable to the Federal Government--however, the On-Scene-Commander and his staff should monitor the complete cleanup operation. Should progress of the cleanup be not to the satisfaction of the On-Scene-Commander, he has the authority to make the company stop its operations and have the Federal government proceed with the cleanup. All cost borne by the Federal government will be reimbursed by the polluter.

B The individual state government can assume command of a spill cleanup, if they so desire. But again, the Federal government's On-Scene-Commander must monitor all phases of the cleanup. The states in turn can recover expended funds either through the individual state courts or the monies can be recovered through the Federal courts.

C The Federal government has established a thirty-five million dollar revolving fund for the cleanup of oil and other hazardous materials. This fund is administered by the U.S. Coast Guard. All monies expended by the Federal government in the cleanup process, will be recovered from the polluter, either voluntarily or through the Federal court system.

VI INDEPENDENT CONTRACTORS FOR CLEANUP

A Prior to the Torrey Canyon incident, it was very difficult to find a contractor who had the knowledge of oil spill cleanup or the desire to cleanup massive spills of oil. However, since that date, a new industry has evolved - the so-called "third party contractor" for the cleanup of oil spills.

B As mentioned previously, the On-Scene-Commander should have on his staff a responsible contracting officer. The contracting officer should handle all the details of the contract, payment and the keeping of complete records pertaining to all monies expended during the life of the spill. The On-Scene-Commander and the contracting officer should keep in mind that all paper work involved in cleanup cost will probably end up as evidence in a federal court.

C Prior to a major spill, a good On-Scene-Commander should have knowledge of all "third party" contractors in his area of responsibility. The On-Scene-Commander should know the people he is going to be working with during an emergency. He should know the amount of equipment the contractor has on hand, the type of equipment, the conditions of the equipment. He should know if the contractor has trained personnel or does he recruit from the streets. All this knowledge is important to the On-Scene-Commander, for he has to rely heavily on his working contractors.

D Finally, the On-Scene-Commander should have available to him trained personnel to monitor the work of the various contractors in the field. This is necessary to insure that the Federal government receives full value for every dollar spent on the cleanup.

VII REPORTS REQUIRED

A The National Contigency Plan requires that the On-Scene-Commander submit two situation reports daily. On at 0800 hours and one at 2000 hours. These reports are normally submitted by teletype. If any event of dramatic importance occurs at other times of the day, the National Response Team should be notified by teletype at once.

B When the emergency is over, and the Regional Response Team is disbanded, the On-Scene-Commander should prepare his "End of Operations" report. This report should contain as much information as possible about the entire life of the spill incident. The Commander's Log will prove invaluable to the On-Scene-Commander's preparation of his report. Once completed, the report should be forwarded to the National Response Team through the Regional Response Team.

This outline was prepared by H. J. Lamp'l, Contigency Plans Officer, Emergency Response Branch, Region II, EPA, Edison, Nj 08817.

EPA OIL POLLUTION PREVENTION REGULATIONS

I INTRODUCTION

Section 311(b) (1) of the Federal Water Pollution Control Act Amendments of 1972 declares that there shall be no discharges of oil or hazardous substances into or upon the navigable waters of the United States, adjoining shoreline or into or upon the waters of the contigious zone. Consistent with this policy, Section 311(J) (1) (C) requires that the President issue regulations to establish procedures, methods and equipment, and other requirements for equipment to prevent the discharge of oil or hazardous substances from vessels and onshore and offshore facilities and to contain such discharges. The EPA, after careful consideration and evaluation of Federal, regional, state and local water quality laws, rules and regulations, as well as rules of regulatory agencies in oil producing states and fire and insurance underwriter codes, established that the most effective method to meet the policy goal of FWPCA is to require that owners and operators of non-transportation related facilities develop and implement Spill Prevention, Control and Countermeasure (SPCC) Plans. This approach places the responsibility of oil prevention on the owner or operator of a non-transportation related facility which can reasonable be expected to discharge oil into U.S. navigable waters.

Regulations governing Oil Pollution Prevention for Non-Transportation Related On-Shore and Off-Shore Facilities were issued in the Federal Register on December 11, 1973, Volume 38, Number 237, Part V. These regulations define the purpose and requirements for preparation and implementation of SPCC plans and civil penalties for failure to comply with such requirements. Guidlines for Preparation and Implementation of the SPCC are also provided. The regulations became effective January 10, 1974.

A copy of the regulations is attached to this outline.

These regulations relate specifically to oil of any kind or in any form. It is anticipated that other regulations will be proposed with respect to discharges of hazardous substances in the near future.

II PROGRAM APPLICABILITY

A The purpose of the Oil Pollution Prevention Regulations is to prevent the discharge of oil from non-transportation related onshore and offshore facilities into or upon the navigable waters of the United States.

B The regulation applies to:

1 Owners or operators of non-transportation related onshore and offshore facilities engaged in drilling, producing, gathering, processing, refining, transferring, distributing or consuming oil and oil products, which due to their location, can reasonably be expected to discharge oil in harmful quantities as defined by 40 CFR Part 110. Mobile and stationary facilities must comply with the requirements of the regulation.

2 All departments, agencies, and instrumentalities of the Federal Government, except that part which applies to civil penalties.

C The regulation does not apply to:

1 Transportation related facilities which are subject to the authority and control of the Department of Transportation as defined by the Memorandum of Understanding between the Secretary of Transportation and the Administrator of the Environmental Protection Agency dated

November 24, 1971, 36 FR 24000. Transportation related facilities generally relate to: vessels; vessel related transfer facilities, including transfer hoses, loading arms, storage tanks for reception of oil ballast water or tank washings from vessels and appurtenances; equipment appurtenant to a non-transportation related facility that is primarily used to transfer oil in bulk to or from a vessel; inter or intrastate pipeline systems including pumps and appurtenances as well as in-line or breakout storage tanks; and highway vehicles and railroad cars used for transporting oil in the inter or intrastate commerce.

2 Facilities with aggregate above ground storage of 1320 gallons or less provided no single container has a capacity in excess of 660 gallons.

3 Facilities with a total storage capacity of 42000 gallons or less and such storage is buried underground.

4 Non-transportation related on-shore or off-shore facilities which due to location could not reasonable be expected to discharge oil into or upon the navigable waters of the United States or adjoining shorelines.

III PROGRAM IMPLEMENTATION

A Owners and operators who have discharged or could reasonably be expected to discharge oil in harmful quantities as defined in 40 CFR Part 110 into or upon navigable waters of the United States shall prepare an SPCC Plan in accordance with Section 112.7, Oil Pollution Prevention Regulation.

1 Such SPCC Plan shall be prepared within six months after the effective date of January 10, 1974, and shall be fully implemented as soon as possible but not later than one year after January 10, 1974.

2 New facilities that become operational after the effective date of the regulation that have discharged or can reasonably be expected to discharge a harmful quantity of oil into or upon navigable waters should be carried by an SPCC. Such a plan shall be prepared within 6 months after the date the plant commenced operation and shall be implemented one year from that date.

3 On-shore and off-shore mobile or portable facilities shall also prepare and implement a SPCC Plan. Such SPCC Plans need not be prepared and implemented each time the facility is moved to a new site.

4 Each SPCC Plan shall be reviewed by a Professional Engineer who will certify that the plan fulfills the requirements of the Oil Prevention Regulation and has been prepared in accordance with good engineering practices. Such certification, however, shall in no way relieve the owner or operator of his duty to prepare and fully implement the plan.

IV EXTENSION OF TIME

A The Regional Administrator may authorize an extension of time for preparation and implementation of the SPCC Plan when he finds that inability to comply with the required schedule is result of nonavailability of qualified personnel or delays in construction of equipment delivery. A request for extension will not relieve the owner or operator from his obligation to comply with requirements of the regulation.

B Any request for time extension may be submitted by letter to the Regional Administrator and shall include:

1 a complete copy of the SPCC Plan if completed;

2 a full explanation of cause for delay;

3 a description of the specific aspects of the Plan affected by the delay;

4 a full discussion of actions being taken or planned to minimize or mitigate the delay;

5 a proposed time schedule for implementing any corrective actions being taken or contemplated;

6 any other oral or written statements in support of the request.

C Authorization for an extension of time does not mitigate the owners or operators responsibility for implementing those aspects of the SPCC Plan not affected by the extension of time.

V AMENDMENT OF SPCC PLANS

A An SPCC Plan shall be submitted to the Regional Administrator for review when the facility has:

1 discharged more than 1000 U.S. gallons of oil into or upon navigable waters or adjoining shoreline in a single spill event; or

2 discharged oil in harmful quantities as defined in 40 CFR Part 110 into or upon navigable waters or adjoining shoreline in two spill events, reportable under Section 311(b) (5) of the FWPCA, within any 12-month period.

B SPCC Plan submission shall be made within 60 days from the time such facility becomes subject to the requirements of the regulations as defined above.

C Each submission of an SPCC Plan shall include:

1 name of facility;

2 names(s) of owner or operator;

3 location of facility;

4 date and year of initial facility operation;

5 maximum storage or handling facilities and normal daily throughput;

6 description of facility including maps, flow diagrams, and topographical maps;

7 a complete copy of SPCC Plan with any amendments;

8 causes(s) of spill;

9 corrective action and/or countermeasures;

10 additional preventive measures taken or contemplated to minimize the possibility of recurrence;

11 other information as reasonably required by the Regional Administrator.

D The Regional Administrator after review of the SPCC Plan may determine that an amendment is necessary to prevent and contain discharges of oil from the facility. The Admendment becomes effective 30 days after the owner or operator has been notified.

E An owner or operator may appeal the Regional Administrator's required amendment. The appeal shall be made in writing to the Administrator of the U. S. Environmental Protection Agency within 30 days of receipt of the notice from the Regional Adminstrator. The Administrator shall render a decision within 60 days of receipt of the appeal.

F Owners or operators shall amend SPCC Plans whenever there is a change in facility design, construction, operation or maintenance which materially affects the facility's potential for oil spills. In addition, each SPCC Plan shall be reviewed and evaluated at least once every three years from the date the facility becomes subject to the regulation.

VI CIVIL PENALTIES

A Owners or operators of facilities subject to the regulation who fail to comply with the requirements of the regulation shall be liable for a civil penalty of not more than $5000 for each day that such failure continues.

VII GUIDELINES FOR PREPARATION OF SPCC

A The SPCC Plan should follow the sequence and guidelines contained in Section 112.7 of the Oil Pollution Prevention Regulations. The Plan should be carefully prepared and should incorporate good engineering practices. It requires the full approval of management at a level with the authority to commit resources. The SPCC Plan should include:

1 describe each spill, corrective action taken and plans to prevent reoccurence when a facility has experienced one or more spill events within 12 months prior to the effective date of the regulation;

2 a prediction of direction, rate of flow and total quantity of oil that can be discharged when experience indicates a reasonable potential for spills due to equipment failure.

3 containment and/or diversionary facilities should prevent discharged oil from reaching a navigable water:

a for onshore facilities - dikes, berms or retaining walls, curbing, culverts, gutters and drainage systems, weirs and booms, diversion and retention ponds, and sorbent materials.

b for offshore facilities - curbing, drip pans, sumps and collection systems.

B The Plan should further consider the guidelines contained in Section 112.7.

1 Onshore facilities (excluding production):

a drainage

b bulk storage

c facility transfer operations

d facility tank car and tank truck loading/unloading rack

2 Onshore Facilities (Production)

a drainage

b bulk storage

c facility transfer operations

3 Oil Drilling and Workover Facilities (Onshore)

4 Oil Drilling Production or Workover Facilities (Offshore)

5 Inspections and Records

6 Security (excluding Oil Production Facilities)

7 Personnel, training and spill prevention procedures

This outline was prepared by William J. Librizzi, Jr., Chief, Emergency Response Branch, Surveillance and Analysis Division, Region II, EPA, Edison, NJ 08817.

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PART II

ENVIRONMENTAL PROTECTION AGENCY

■

OIL POLLUTION PREVENTION

Non-Transportation Related Onshore and Offshore Facilities

30-6

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 112—OIL POLLUTION PREVENTION

Non-transportation Related Onshore and Offshore Facilities

Notice of proposed rule making was published on July 19, 1973, containing proposed regulations, required by an pursuant to section 311(j)(1)(C) of the Federal Water Pollution Control Act, as amended (86 Stat. 868, 33 U.S.C. 1251 et seq.), (FWPCA), to prevent discharges of oil into the navigable waters of the United States and to contain such discharges if they occur. The proposed regulations endeavor to prevent such spills by establishing procedures, methods and equipment requirements of owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, distributing, or consuming oil.

Written comments on the proposed regulations were solicited and received from interested parties. In addition, a number of verbal comments on the proposal were also received. The written comments are on file at the Division of Oil and Hazardous Materials, Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C.

All of the comments have been given careful consideration and a number of changes have been made in the regulation. These changes incorporate either suggestions made in the comments or ideas initiated by the suggestions.

Some comments reflected a misunderstanding of the fundamental principles of the regulation, specifically as they applied to older facilities and marginal operations. During the development of the regulation it was recognized that no single design or operational standard can be prescribed for all non-transportation related facilities, since the equipment and operational procedures appropriate for one facility may not be appropriate for another because of factors such as function, location, and age of each facility. Also, new facilities could achieve a higher level of spill prevention than older facilities by the use of fail-safe design concepts and innovative spill prevention methods and procedures. It was concluded that older facilities and marginal operations could develop strong spill contingency plans and commit manpower, oil containment devices and removal equipment to compensate for inherent weaknesses in the spill prevention plan.

Appropriate changes were made in the regulation to simplify, clarify or correct deficiencies in the proposal.

A discussion of these changes, section by section follows:

A. *Section 112.1—General applicability.* Section 112.1(b), the "foreseeability provision", contained in 112.1(d)(4) was added to paragraph 112.1(b). As modified, the regulation applies to non-transportation-related onshore and offshore facilities which, due to their location, could reasonably be expected to discharge oil into or upon the navigable waters of the United States or adjoining shorelines.

Sections 112.1(b), 112.1(d)(4) and 112.3 are now consistent.

Section 112.1(d)(1) was expanded to further clarify the respective authorities of the Department of Transportation and the Environmental Protection Agency by referring to the Memorandum of Understanding between the Secretary of Transportation and the Administrator of the Environmental Protection Agency (Appendix).

Section 112.1(d)(2), the figure for barrels was converted to gallons, a unit of measure more familiar to the public, and now reads "42000 gallons."

Section 112.1(d)(3), exemption for facilities with nonburied tankage was extended to 1320 gallons in aggregate with no single tank larger than 660 gallons and applies to all oils, not just heating oil and motor fuel. Tanks of 660 gallons are the normal domestic code size for nonburied heating oil tanks. Buildings may have two such tanks. Facilities containing small quantities of oil other than motor fuel or heating oil would also be exempt, thus making this consistent with the definition of oil in § 112.2.

B. *Section 112.2—Definitions.* Section 112.2(1), the term "navigable waters" was expanded to the more descriptive definition used by the National Pollutant Discharge Elimination System.

Section 112.2(m), the U.S. Coast Guard definition of the term "vessel" was included. This term is used in the regulation and the definition is consistent with the Department of Transportation regulations.

C. *Section 112.3—Requirements for the preparation and implementation of spill prevention control and countermeasure plans.* A new paragraph (c) was added to § 112.3 which applies to mobile or portable facilities subject to the regulation. These facilities need not prepare a new Spill Prevention Control and Countermeasure Plan (SPCC Plan) each time the facility is moved to a new site, but may prepare a general plan, identifying good spill prevention engineering practices (as outlined in the guidelines, § 112.7), and implement these practices at each new location.

Section 112.3(a), (b) and (f) (which was § 112.3(e) in the proposed rule making) have been modified to allow extensions of time beyond the normally specified periods to apply to the preparation of plans as well as to their implementation and to remove the time limitation of one year for extensions. Extensions may be allowed for whatever period of time considered reasonable by the Regional Administrator.

Section 112.3(e) (which was § 112.3 (d) in the proposed rule making) was modified to require the maintenance of the SPCC Plan for inspection at the facility only if the facility was normally manned. If the facility is unmanned, the Plan may be kept at the nearest field office.

Section 112.3(f)(1) (§ 112.3(e)(1) in the proposed regulation) was changed to include the nonavailability of qualified personnel as a reason for the Regional Administrator granting an extension of time.

D. *Section 112.4—Amendment of spill prevention control and countermeasure plans by Regional Administrator.* Section 112.4(a)(11), permits the Regional Administrator to require that the owner or operator furnish additional information to EPA after one or more spill event has occurred. The change limits the request for additional information to that pertinent to the SPCC Plan or to the pollution incident.

Section 112.4(b) now reads "Section 112.4 * * *", not "This subsection * * *"

Section 112.4(e) allowed the Regional Administrator to require amendments to SPCC Plans and specifies that the amendment must be incorporated in the Plan within 30 days unless the Regional Administrator specifies an earlier effective date. The change allows the Regional Administrator to specify any appropriate date that is reasonable.

Section 112.4(f). A new § 112.4(f) has been added which provides for an appeal by an owner or operator from a decision rendered by the Regional Administrator on an amendment to an SPCC Plan. The appeal is made to the Administrator of EPA and the paragraph outlines the procedures for making such an appeal.

E. *Section 112.5—Amendment of spill prevention control and countermeasure plans by owners or operators.* Section 112.5(b) required the owner or operator to amend the SPCC Plan every three years. The amendment required the incorporation of any new, field-proven technology and had to be certified by a Professional Engineer.

The change requires that the owner or operator review the Plan every three years to see if it needs amendment. New technology need be incorporated only if it will significantly reduce the likelihood of a spill. The change will prevent frivolous retrofitting of equipment to facilities whose prevention plans are working successfully, and will not require engineering certification unless an amendment is necessary.

Section 112.5(c), this paragraph required that the owner or operator amend his SPCC Plan when his facility became subject to §112.4 (amendment by the Regional Administrator). This paragraph has been removed. It is inconsistent to require the owner or operator to independently amend the Plan while the Regional Administrator is reviewing it for possible amendment.

F. *Section 112.6—Civil penalties.* There are no changes in this section.

G. *Section 112.7—Guidelines for the preparation and implementation of a spill prevention control and countermeasure plan.* Numerous changes have been made in the guidelines section; the changes have been primarily:

1. To correct the use of language inconsistent with guidelines. For example, the word "shall" has been changed to "should" in § 112.7(a) through (e).

2. To give the engineer preparing the Plan greater latitude to use alternative methods better suited to a given facility or local conditions.

3. To cover facilities subject to the regulation, but for which no guidelines were previously given. This category includes such things as mobile facilities, and drilling and workover rigs.

In addition, wording was changed to differentiate between periodic observations by operating personnel and formal inspections with attendant record keeping.

These regulations shall become effective January 10, 1974.

Dated: November 27, 1973.

JOHN QUARLES,
Acting Administrator.

A new Part 112 would be added to subchapter D, Chapter I of Title 40, Code of Federal Regulations as follows:

Sec.
112.1 General applicability.
112.2 Definitions.
112.3 Requirements for preparation and implementation of Spill Prevention Control and Countermeasure plans.
112.4 Amendment of Spill Prevention Control and Countermeasure Plans by Regional Administrator.
112.5 Admendment of Spill Prevention Control and Countermeasure Plans by owners or operators.
112.6 Civil penalties.
112.7 Guidelines for the preparation and implementation of a Spill Prevention Control and Countermeasure Plan.
Appendix Memorandum of Understanding Between the Secretary of the Department of Transportation and the Administrator of the Environmental Protection Agency. Section II—Definitions.

AUTHORITY: Secs. 311(j)(1)(C), 311(j)(2), 501(a), Federal Water Pollution Control Act (Sec. 2, Pub. L. 92–500, 86 Stat. 816 et seq. (33 U.S.C. 1251 et seq.)); Sec. 4(b), Pub. L. 92–500, 86 Stat. 897; 5 U.S.C. Reorg. Plan of 1970 No. 3 (1970), 35 FR 15623, 3 CFR 1966–1970 Comp.; E.O. 11735, 38 FR 21243, 3 CFR.

§ 112.1 General applicability.

(a) This part establishes procedures, methods and equipment and other requirements for equipment to prevent the discharge of oil from non-transportation-related onshore and offshore facilities into or upon the navigable waters of the United States or adjoining shorelines.

(b) Except as provided in paragraph (d) of this section, this part applies to owners or operators of non-transportation-related onshore and offshore facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, distributing or consuming oil and oil products, and which, due to their location, could reasonably be expected to discharge oil in harmful quantities, as defined in Part 110 of this chapter, into or upon the navigable waters of the United States or adjoining shorelines.

(c) As provided in sec. 313 (86 Stat. 875) departments, agencies, and instrumentalities of the Federal government are subject to these regulations to the same extent as any person, except for the provisions of § 112.6.

(d) This part does not apply to:

(1) Equipment or operations of vessels or transportation-related onshore and offshore facilities which are subject to authority and control of the Department of Transportation, as defined in the Memorandum of Understanding between the Secretary of Transportation and the Administrator of the Environmental Protection Agency, dated November 24, 1971, 36 FR 24000.

(2) Facilities which have an aggregate storage of 1320 gallons or less of oil, provided no single container has a capacity in excess of 660 gallons.

(3) Facilities which have a total storage capacity of 42000 gallons or less of oil and such total storage capacity is buried underground.

(4) Non-transportation-related onshore and offshore facilities, which, due to their location, could not reasonably be expected to discharge oil into or upon the navigable waters of the United States or adjoining shorelines.

(e) This part provides for the preparation and implementation of Spill Prevention Control and Countermeasure Plans prepared in accordance with § 112.7, designed to complement existing laws, regulations, rules, standards, policies and procedures pertaining to safety standards, fire prevention and pollution prevention rules, so as to form a comprehensive balanced Federal/State spill prevention program to minimize the potential for oil discharges. Compliance with this part does not in any way relieve the owner or operator of an onshore or an offshore facility from compliance with other Federal, State or local laws.

§ 112.2 Definitions.

For the purposes of this part:

(a) "Oil" means oil of any kind or in any form, including, but not limited to petroleum, fuel oil, sludge, oil refuse and oil mixed with wastes other than dredged spoil.

(b) "Discharge" includes but is not limited to, any spilling, leaking, pumping, pouring, emitting, emptying or dumping. For purposes of this part, the term "discharge" shall not include any discharge of oil which is authorized by a permit issued pursuant to Section 13 of the River and Harbor Act of 1899 (30 Stat. 1121, 33 U.S.C. 407), or Sections 402 or 405 of the FWPCA Amendments of 1972 (86 Stat. 816 et seq., 33 U.S.C. 1251 et seq.).

(c) "Onshore facility" means any facility of any kind located in, on, or under any land within the United States, other than submerged lands, which is not a transportation-related facility.

(d) "Offshore facility" means any facility of any kind located in, on, or under any of the navigable waters of the United States, which is not a transportation-related facility.

(e) "Owner or operator" means any person owning or operating an onshore facility or an offshore facility, and in the case of any abandoned offshore facility, the person who owned or operated such facility immediately prior to such abandonment.

(f) "Person" includes an individual, firm corporation, association, and a partnership.

(g) "Regional Administrator", means the Regional Administrator of the Environmental Protection Agency, or his designee, in and for the Region in which the facility is located.

(h) "Transportation-related" and "non-transportation-related" as applied to an onshore or offshore facility, are defined in the Memorandum of Understanding between the Secretary of Transportation and the Administrator of the Environmental Protection Agency, dated November 24, 1971, 36 FR 24080.

(i) "Spill event" means a discharge of oil into or upon the navigable waters of the United States or adjoining shorelines in harmful quantities, as defined at 40 CFR Part 110.

(j) "United States" means the States, the District of Columbia, the Commonwealth of Puerto Rico, the Canal Zone, Guam, American Samoa, the Virgin Islands, and the Trust Territory of the Pacific Islands.

(k) The term "navigable waters" of the United States means "navigable waters" as defined in section 502(7) of the FWPCA, and includes:

(1) all navigable waters of the United States, as defined in judicial decisions prior to passage of the 1972 Amendments to the FWPCA (Pub. L. 92–500), and tributaries of such waters;

(2) interstate waters;

(3) intrastate lakes, rivers, and streams which are utilized by interstate travelers for recreational or other purposes; and

(4) intrastate lakes, rivers, and streams from which fish or shellfish are taken and sold in interstate commerce.

(l) "Vessel" means every description of watercraft or other artificial contrivance used, or capable of being used as a means of transportation on water, other than a public vessel.

§ 112.3 Requirements for preparation and implementation of Spill Prevention Control and Countermeasure Plans.

(a) Owners or operators of onshore and offshore facilities in operation on or before the effective date of this part that have discharged or could reasonably be expected to discharge oil in harmful quantities, as defined in 40 CFR Part 110, into or upon the navigable waters of the United States or adjoining shorelines, shall prepare a Spill Prevention Control and Countermeasure Plan (hereinafter "SPCC Plan"), in accordance with § 112.7. Except as provided for in paragraph (f) of this section, such SPCC Plan shall be prepared within six months after the effective date of this part and shall be fully implemented as soon as possible, but not later than one year after the effective date of this part.

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(b) Owners or operators of onshore and offshore facilities that become operational after the effective date of this part, and that have discharged or could reasonably be expected to discharge oil in harmful quantities, as defined in 40 CFR Part 110, into or upon the navigable waters of the United States or adjoining shorelines, shall prepare an SPCC Plan in accordance with § 112.7. Except as provided for in paragraph (f) of this section, such SPCC Plan shall be prepared within six months after the date such facility begins operations and shall be fully implemented as soon as possible, but not later than one year after such facility begins operations.

(c) Onshore and offshore mobile or portable facilities such as onshore drilling or workover rigs, barge mounted offshore drilling or workover rigs, and portable fueling facilities shall prepare and implement an SPCC Plan as required by paragraphs (a), (b) and (d) of this section. The owner or operator of such facility need not prepare and implement a new SPCC Plan each time the facility is moved to a new site. The SPCC Plan for mobile facilities should be prepared in accordance with § 112.7, using good engineering practice, and when the mobile facility is moved it should be located and installed using spill prevention practices outlined in the SPCC Plan for the facility. The SPCC Plan shall only apply while the facility is in a fixed (non transportation) operating mode.

(d) No SPCC Plan shall be effective to satisfy the requirements of this part unless it has been reviewed by a Registered Professional Engineer and certified to by such Professional Engineer. By means of this certification the engineer, having examined the facility and being familiar with the provisions of this part, shall attest that the SPCC Plan has been prepared in accordance with good engineering practices. Such certification shall in no way relieve the owner or operator of an onshore or offshore facility of his duty to prepare and fully implement such Plan in accordance with § 112.7, as required by paragraphs (a), (b) and (c) of this section.

(e) Owners or operators of a facility for which an SPCC Plan is required pursuant to paragraphs (a), (b) or (c) of this section shall maintain a complete copy of the Plan at such facility if the facility is normally attended at least 8 hours per day, or at the nearest field office if the facility is not so attended, and shall make such Plan available to the Regional Administrator for on-site review during normal working hours.

(f) Extensions of time.

(1) The Regional Administrator may authorize an extension of time for the preparation and full implementation of an SPCC Plan beyond the time permitted for the preparation and implementation of an SPCC Plan pursuant to paragraphs (a), (b) or (c) of this section where he finds that the owner or operator of a facility subject to paragraphs (a), (b) or (c) of this section cannot fully comply with the requirements of this part as a result of either nonavailability of qualified personnel, or delays in construction or equipment delivery beyond the control and without the fault of such owner or operator or their respective agents or employees.

(2) Any owner or operator seeking an extension of time pursuant to paragraph (f)(1) of this section may submit a letter of request to the Regional Administrator. Such letter shall include:

(i) A complete copy of the SPCC Plan, if completed;

(ii) A full explanation of the cause for any such delay and the specific aspects of the SPCC Plan affected by the delay;

(iii) A full discussion of actions being taken or contemplated to minimize or mitigate such delay;

(iv) A proposed time schedule for the implementation of any corrective actions being taken or contemplated, including interim dates for completion of tests or studies, installation and operation of any necessary equipment or other preventive measures.

In addition, such owner or operator may present additional oral or written statements in support of his letter of request.

(3) The submission of a letter of request for extension of time pursuant to paragraph (f)(2) of this section shall in no way relieve the owner or operator from his obligation to comply with the requirements of § 112.3 (a), (b) or (c). Where an extension of time is authorized by the Regional Administrator for particular equipment or other specific aspects of the SPCC Plan, such extension shall in no way affect the owner's or operator's obligation to comply with the requirements of § 112.3 (a), (b) or (c) with respect to other equipment or other specific aspects of the SPCC Plan for which an extension of time has not been expressly authorized.

§ 112.4 Amendment of SPCC Plans by Regional Administrator.

(a) Notwithstanding compliance with § 112.3, whenever a facility subject to § 112.3 (a), (b) or (c) has: Discharged more than 1,000 U.S. gallons of oil into or upon the navigable waters of the United States or adjoining shorelines in a single spill event, or discharged oil in harmful quantities, as defined in 40 CFR Part 110, into or upon the navigable waters of the United States or adjoining shorelines in two spill events, reportable under section 311(b)(5) of the FWPCA, occurring within any twelve month period, the owner or operator of such facility shall submit to the Regional Administrator, within 60 days from the time such facility becomes subject to this section, the following:

(1) Name of the facility;

(2) Name(s) of the owner or operator of the facility;

(3) Location of the facility;

(4) Date and year of initial facility operation;

(5) Maximum storage or handling capacity of the facility and normal daily throughput;

(6) Description of the facility, including maps, flow diagrams, and topographical maps;

(7) A complete copy of the SPCC Plan with any amendments;

(8) The cause(s) of such spill, including a failure analysis of system or subsystem in which the failure occurred;

(9) The corrective actions and/or countermeasures taken, including an adequate description of equipment repairs and/or replacements;

(10) Additional preventive measures taken or contemplated to minimize the possibility of recurrence;

(11) Such other information as the Regional Administrator may reasonably require pertinent to the Plan or spill event.

(b) Section 112.4 shall not apply until the expiration of the time permitted for the preparation and implementation of an SPCC Plan pursuant to § 112.3 (a), (b), (c) and (f).

(c) A complete copy of all information provided to the Regional Administrator pursuant to paragraph (a) of this section shall be sent at the same time to the State agency in charge of water pollution control activities in and for the State in which the facility is located. Upon receipt of such information such State agency may conduct a review and make recommendations to the Regional Administrator as to further procedures, methods, equipment and other requirements for equipment necessary to prevent and to contain discharges of oil from such facility.

(d) After review of the SPCC Plan for a facility subject to paragraph (a) of this section, together with all other information submitted by the owner or operator of such facility, and by the State agency under paragraph (c) of this section, the Regional Administrator may require the owner or operator of such facility to amend the SPCC Plan if he finds that the Plan does not meet the requirements of this part or that the amendment of the Plan is necessary to prevent and to contain discharges of oil from such facility.

(e) When the Regional Administrator proposes to require an amendment to the SPCC Plan, he shall notify the facility operator by certified mail addressed to, or by personal delivery to, the facility owner or operator, that he proposes to require an amendment to the Plan, and shall specify the terms of such amendment. If the facility owner or operator is a corporation, a copy of such notice shall also be mailed to the registered agent, if any, of such corporation in the State where such facility is located. Within 30 days from receipt of such notice, the facility owner or operator may submit written information, views, and arguments on the amendment. After considering all relevant material presented, the Regional Administrator shall notify the facility owner or operator of any amendment required or shall rescind the notice. The amendment required by the Regional Administrator shall become part of the Plan 30 days after such notice, unless the Regional Administrator, for good cause, shall specify another effective date. The owner or operator of the facility shall implement the amendment of the Plan as soon as possible, but not later than six months after the amendment becomes part of the Plan, unless the Regional Administrator specifies another date.

(f) An owner or operator may appeal a decision made by the Regional Administrator requiring an amendment to an SPCC Plan. The appeal shall be made to the Administrator of the United States Environmental Protection Agency and must be made in writing within 30 days of receipt of the notice from the Regional Administrator requiring the amendment. A complete copy of the appeal must be sent to the Regional Administrator at the time the appeal is made. The appeal shall contain a clear and concise statement of the issues and points of fact in the case. It may also contain additional information which the owner or operator wishes to present in support of his argument. The Administrator or his designee may request additional information from the owner or operator, or from any other person. The Administrator or his designee may request additional information from the owner or operator, or from any other person. The Administrator or his designee shall render a decision within 60 days of receiving the appeal and shall notify the owner or operator of his decision.

§ 112.5 Amendment of Spill Prevention Control and Countermeasure Plans by owners or operators.

(a) Owners or operators of facilities subject to § 112.3 (a), (b) or (c) shall amend the SPCC Plan for such facility in accordance with § 112.7 whenever there is a change in facility design, construction, operation or maintenance which materially affects the facility's potential for the discharge of oil into or upon the navigable waters of the United States or adjoining shorelines. Such amendments shall be fully implemented as soon as possible, but not later than six months after such change occurs.

(b) Notwithstanding compliance with paragraph (a) of this section, owners and operators of facilities subject to § 112.3 (a), (b) or (c) shall complete a review and evaluation of the SPCC Plan at least once every three years from the date such facility becomes subject to this part. As a result of this review and evaluation, the owner or operator shall amend the SPCC Plan within six months of the review to include more effective prevention and control technology if: (1) Such technology will significantly reduce the likelihood of a spill event from the facility, and (2) if such technology has been field-proven at the time of the review.

(c) No amendment to an SPCC Plan shall be effective to satisfy the requirements of this section unless it has been certified by a Professional Engineer in accordance with § 112.3(d).

§ 112.6 Civil penalties.

Owners or operators of facilities subject to § 112.3 (a), (b) or (c) who violate the requirements of this part by failing or refusing to comply with any of the provisions of § 112.3, § 112.4, or § 112.5 shall be liable for a civil penalty of not more than $5,000 for each day that such violation continues. The Regional Administrator may assess and compromise such civil penalty. No penalty shall be assessed until the owner or operator shall have been given notice and an opportunity for hearing.

§ 112.7 Guidelines for the preparation and implementation of a Spill Prevention Control and Countermeasure Plan.

The SPCC Plan shall be a carefully thought-out plan, prepared in accordance with good engineering practices, and which has the full approval of management at a level with authority to commit the necessary resources. If the plan calls for additional facilities or procedures, methods, or equipment not yet fully operational, these items should be discussed in separate paragraphs, and the details of installation and operational start-up should be explained separately. The complete SPCC Plan shall follow the sequence outlined below, and include a discussion of the facility's conformance with the appropriate guidelines listed:

(a) A facility which has experienced one or more spill events within twelve months prior to the effective date of this part should include a written description of each such spill, corrective action taken and plans for preventing recurrence.

(b) Where experience indicates a reasonable potential for equipment failure (such as tank overflow, rupture, or leakage), the plan should include a prediction of the direction, rate of flow, and total quantity of oil which could be discharged from the facility as a result of each major type of failure.

(c) Appropriate containment and/or diversionary structures or equipment to prevent discharged oil from reaching a navigable water course should be provided. One of the following preventive systems or its equivalent should be used as a minimum:

(1) Onshore facilities.

(i) Dikes, berms or retaining walls sufficiently impervious to contain spilled oil

(ii) Curbing

(iii) Culverting, gutters or other drainage systems

(iv) Weirs, booms or other barriers

(v) Spill diversion ponds

(vi) Retention ponds

(vii) Sorbent materials

(2) Offshore facilities.

(i) Curbing, drip pans

(ii) Sumps and collection systems

(d) When it is determined that the installation of structures or equipment listed in § 112.7(c) to prevent discharged oil from reaching the navigable waters is not practicable from any onshore or offshore facility, the owner or operator should clearly demonstrate such impracticability and provide the following:

(1) A strong oil spill contingency plan following the provision of 40 CFR Part 109.

(2) A written commitment of manpower, equipment and materials required to expeditiously control and remove any harmful quantity of oil discharged.

(e) In addition to the minimal prevention standards listed under § 112.7 (c), sections of the Plan should include a complete discussion of conformance with the following applicable guidelines, other effective spill prevention and containment procedures (or, if more stringent, with State rules, regulations and guidelines):

(1) *Facility drainage (onshore); (excluding production facilities).* (i) Drainage from diked storage areas should be restrained by valves or other positive means to prevent a spill or other excessive leakage of oil into the drainage system or inplant effluent treatment system, except where plan systems are designed to handle such leakage. Diked areas may be emptied by pumps or ejectors; however, these should be manually activated and the condition of the accumulation should be examined before starting to be sure no oil will be discharged into the water.

(ii) Flapper-type drain valves should not be used to drain diked areas. Valves used for the drainage of diked areas should, as far as practical, be of manual, open-and-closed design. When plant drainage drains directly into water courses and not into wastewater treatment plants, retained storm water should be inspected as provided in paragraph (e)(2)(iii) (B, C and D) before drainage.

(iii) Plant drainage systems from undiked areas should, if possible, flow into ponds, lagoons or catchment basins, designed to retain oil or return it to the facility. Catchment basins should not be located in areas subject to periodic flooding.

(iv) If plant drainage is not engineered as above, the final discharge of all in-plant ditches should be equipped with a diversion system that could, in the event of an uncontrolled spill, return the oil to the plant.

(v) Where drainage waters are treated in more than one treatment unit, natural hydraulic flow should be used. If pump transfer is needed, two "lift" pumps should be provided, and at least one of the pumps should be permanently installed when such treatment is continuous. In any event, whatever techniques are used facility drainage systems should be adequately engineered to prevent oil from reaching navigable waters in the event of equipment failure or human error at the facility.

(2) *Bulk storage tanks (onshore); (excluding production facilities).* (i) No

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tank should be used for the storage of oil unless its material and construction are compatible with the material stored and conditions of storage such as pressure and temperature, etc.

(ii) All bulk storage tank installations should be constructed so that a secondary means of containment is provided for the entire contents of the largest single tank plus sufficient freeboard to allow for precipitation. Diked areas should be sufficiently impervious to contain spilled oil. Dikes, containment curbs, and pits are commonly employed for this purpose, but they may not always be appropriate. An alternative system could consist of a complete drainage trench enclosure arranged so that a spill could terminate and be safely confined in an in-plant catchment basin or holding pond.

(iii) Drainage of rainwater from the diked area into a storm drain or an effluent discharge that empties into an open water course, lake, or pond, and bypassing the in-plant treatment system may be acceptable if:

(A) The bypass valve is normally sealed closed.

(B) Inspection of the run-off rain water ensures compliance with applicable water quality standards and will not cause a harmful discharge as defined in 40 CFR 110.

(C) The bypass valve is opened, and resealed following drainage under responsible supervision.

(D) Adequate records are kept of such events.

(iv) Buried metallic storage tanks represent a potential for undetected spills. A new buried installation should be protected from corrosion by coatings, cathodic protection or other effective methods compatible with local soil conditions. Such buried tanks should at least be subjected to regular pressure testing.

(v) Partially buried metallic tanks for the storage of oil should be avoided, unless the buried section of the shell is adequately coated, since partial burial in damp earth can cause rapid corrosion of metallic surfaces, especially at the earth/air interface.

(vi) Aboveground tanks should be subject to periodic integrity testing, taking into account tank design (floating roof, etc.) and using such techniques as hydrostatic testing, visual inspection or a system of non-destructive shell thickness testing. Comparison records should be kept where appropriate, and tank supports and foundations should be included in these inspections. In addition, the outside of the tank should frequently be observed by operating personnel for signs of deterioration, leaks which might cause a spill, or accumulation of oil inside diked areas.

(vii) To control leakage through defective internal heating coils, the following factors should be considered and applied, as appropriate.

(A) The steam return or exhaust lines from internal heating coils which discharge into an open water course should be monitored for contamination, or passed through a settling tank, skimmer, or other separation or retention system.

(B) The feasibility of installing an external heating system should also be considered.

(viii) New and old tank installations should, as far as practical, be fail-safe engineered or updated into a fail-safe engineered installation to avoid spills. Consideration should be given to providing one or more of the following devices:

(A) High liquid level alarms with an audible or visual signal at a constantly manned operation or surveillance station; in smaller plants an audible air vent may suffice.

(B) Considering size and complexity of the facility, high liquid level pump cutoff devices set to stop flow at a predetermined tank content level.

(C) Direct audible or code signal communication between the tank gauger and the pumping station.

(D) A fast response system for determining the liquid level of each bulk storage tank such as digital computers, telepulse, or direct vision gauges or their equivalent.

(E) Liquid level sensing devices should be regularly tested to insure proper operation.

(ix) Plant effluents which are discharged into navigable waters should have disposal facilities observed frequently enough to detect possible system upsets that could cause an oil spill event.

(x) Visible oil leaks which result in a loss of oil from tank seams, gaskets, rivets and bolts sufficiently large to cause the accumulation of oil in diked areas should be promptly corrected.

(xi) Mobile or portable oil storage tanks (onshore) should be positioned or located so as to prevent spilled oil from reaching navigable waters. A secondary means of containment, such as dikes or catchment basins, should be furnished for the largest single compartment or tank. These facilities should be located where they will not be subject to periodic flooding or washout.

(3) *Facility transfer operations, pumping, and in-plant process (onshore); (excluding production facilities)*. (i) Buried piping installations should have a protective wrapping and coating and should be cathodically protected if soil conditions warrant. If a section of buried line is exposed for any reason, it should be carefully examined for deterioration. If corrosion damage is found, additional examination and corrective action should be taken as indicated by the magnitude of the damage. An alternative would be the more frequent use of exposed pipe corridors or galleries.

(ii) When a pipeline is not in service, or in standby service for an extended time the terminal connection at the transfer point should be capped or blank-flanged, and marked as to origin.

(iii) Pipe supports should be properly designed to minimize abrasion and corrosion and allow for expansion and contraction.

(iv) All aboveground valves and pipelines should be subjected to regular examinations by operating personnel at which time the general condition of items, such as flange joints, expansion joints, valve glands and bodies, catch pans, pipeline supports, locking of valves, and metal surfaces should be assessed. In addition, periodic pressure testing may be warranted for piping in areas where facility drainage is such that a failure might lead to a spill event.

(v) Vehicular traffic granted entry into the facility should be warned verbally or by appropriate signs to be sure that the vehicle, because of its size, will not endanger above ground piping.

(4) *Facility tank car and tank truck loading/unloading rack (onshore)*. (i) Tank car and tank truck loading/unloading procedures should meet the minimum requirements and regulation established by the Department of Transportation.

(ii) Where rack area drainage does not flow into a catchment basin or treatment facility designed to handle spills, a quick drainage system should be used for tank truck loading and unloading areas. The containment system should be designed to hold at least maximum capacity of any single compartment of a tank car or tank truck loaded or unloaded in the plant.

(iii) An interlocked warning light or physical barrier system, or warning signs, should be provided in loading/unloading areas to prevent vehicular departure before complete disconnect of flexible or fixed transfer lines.

(iv) Prior to filling and departure of any tank car or tank truck, the lowermost drain and all outlets of such vehicles should be closely examined for leakage, and if necessary, tightened, adjusted, or replaced to prevent liquid leakage while in transit.

(5) *Oil production facilities (onshore)*. (i) *Definition*. An onshore production facility may include all wells, flowlines, separation equipment, storage facilities, gathering lines, and auxiliary non-transportation-related equipment and facilities in a single geographical oil or gas field operated by a single operator.

(ii) *Oil production facility (onshore) drainage*. (A) At tank batteries and central treating stations where an accidental discharge of oil would have a reasonable possibility of reaching navigable waters, the dikes or equivalent required under § 112.7(c)(1) should have drains closed and sealed at all times except when rainwater is being drained. Prior to drainage, the diked area should be inspected as provided in paragraph (e)(2)(iii) (B), C), and (D). Accumulated oil on the rainwater should be picked up and returned to storage or disposed of in accordance with approved methods.

(B) Field drainage ditches, road ditches, and oil traps, sumps or skimmers, if such exist, should be inspected at regularly scheduled intervals for accumulation of oil that may have escaped from small leaks. Any such accumulations should be removed.

(iii) *Oil production facility (onshore) bulk storage tanks*. (A) No tank should be used for the storage of oil unless its material and construction are compatible with the material stored and the conditions of storage.

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(B) All tank battery and central treating plant installations should be provided with a secondary means of containment for the entire contents of the largest single tank if feasible, or alternate systems such as those outlined in § 112.7(c)(1). Drainage from undiked areas should be safely confined in a catchment basin or holding pond.

(C) All tanks containing oil should be visually examined by a competent person for condition and need for maintenance on a scheduled periodic basis. Such examination should include the foundation and supports of tanks that are above the surface of the ground.

(D) New and old tank battery installations should, as far as practical, be fail-safe engineered or updated into a fail-safe engineered installation to prevent spills. Consideration should be given to one or more of the following:

(*1*) Adequate tank capacity to assure that a tank will not overfill should a pumper/gauger be delayed in making his regular rounds.

(*2*) Overflow equalizing lines between tanks so that a full tank can overflow to an adjacent tank.

(*3*) Adequate vacuum protection to prevent tank collapse during a pipeline run.

(*4*) High level sensors to generate and transmit an alarm signal to the computer where facilities are a part of a computer production control system.

(iv) *Facility transfer operations, oil production facility (onshore).* (A) All above ground valves and pipelines should be examined periodically on a scheduled basis for general condition of items such as flange joints, valve glands and bodies, drip pans, pipeline supports, pumping well polish rod stuffing boxes, bleeder and gauge valves.

(B) Salt water (oil field brine) disposal facilities should be examined often, particularly following a sudden change in atmospheric temperature to detect possible system upsets that could cause an oil discharge.

(C) Production facilities should have a program of flowline maintenance to prevent spills from this source. The program should include periodic examinations, corrosion protection, flowline replacement, and adequate records, as appropriate, for the individual facility.

(6) *Oil drilling and workover facilities (onshore)* (i) Mobile drilling or workover equipment should be positioned or located so as to prevent spilled oil from reaching navigable waters.

(ii) Depending on the location, catchment basins or diversion structures may be necessary to intercept and contain spills of fuel, crude oil, or oily drilling fluids.

(iii) Before drilling below any casing string or during workover operations, a blowout prevention (BOP) assembly and well control system should be installed that is capable of controlling any well head pressure that is expected to be encountered while that BOP assembly is on the well. Casing and BOP installations should be in accordance with State regulatory agency requirements.

(7) *Oil drilling, production, or workover facilities (offshore).* (i) Definition: "An oil drilling, production or workover facility (offshore)" may include all drilling or workover equipment, wells, flowlines, gathering lines, platforms, and auxiliary nontransportation-related equipment and facilities in a single geographical oil or gas field operated by a single operator.

(ii) Oil drainage collection equipment should be used to prevent and control small oil spillage around pumps, glands, valves, flanges, expansion joints, hoses, drain lines, separators, treaters, tanks, and allied equipment. Drains on the facility should be controlled and directed toward a central collection sump or equivalent collection system sufficient to prevent discharges of oil into the navigable waters of the United States. Where drains and sumps are not practicable oil contained in collection equipment should be removed as often as necessary to prevent overflow.

(iii) For facilities employing a sump system, sump and drains should be adequately sized and a spare pump or equivalent method should be available to remove liquid from the sump and assure that oil does not escape. A regular scheduled preventive maintenance inspection and testing program should be employed to assure reliable operation of the liquid removal system and pump start-up device. Redundant automatic sump pumps and control devices may be required on some installations.

(iv) In areas where separators and treaters are equipped with dump valves whose predominant mode of failure is in the closed position and pollution risk is high, the facility should be specially equipped to prevent the escape of oil. This could be accomplished by extending the flare line to a diked area if the separator is near shore, equipping it with a high liquid level sensor that will automatically shut-in wells producing to the separator, parallel redundant dump valves, or other feasible alternatives to prevent oil discharges.

(v) Atmospheric storage or surge tanks should be equipped with high liquid level sensing devices or other acceptable alternatives to prevent oil discharges.

(vi) Pressure tanks should be equipped with high and low pressure sensing devices to activate an alarm and/or control the flow or other acceptable alternatives to prevent oil discharges.

(vii) Tanks should be equipped with suitable corrosion protection.

(viii) A written procedure for inspecting and testing pollution prevention equipment and systems should be prepared and maintained at the facility. Such procedures should be included as part of the SPCC Plan.

(ix) Testing and inspection of the pollution prevention equipment and systems at the facility should be conducted by the owner or operator on a scheduled periodic basis commensurate with the complexity, conditions and circumstances of the facility or other appropriate regulations.

(x) Surface and subsurface well shut-in valves and devices in use at the facility should be sufficiently described to determine method of activation or control, e.g., pressure differential, change in fluid or flow conditions, combination of pressure and flow, manual or remote control mechanisms. Detailed records for each well, while not necessarily part of the plan should be kept by the owner or operator.

(xi) Before drilling below any casing string, and during workover operations a blowout preventer (BOP) assembly and well control system should be installed that is capable of controlling any wellhead pressure that is expected to be encountered while that BOP assembly is on the well. Casing and BOP installations should be in accordance with State regulatory agency requirements.

(xii) Extraordinary well control measures should be provided should emergency conditions, including fire, loss of control and other abnormal conditions, occur. The degree of control system redundancy should vary with hazard exposure and probable consequences of failure. It is recommended that surface shut-in systems have redundant or "fail close" valving. Subsurface safety valves may not be needed in producing wells that will not flow but should be installed as required by applicable State regulations.

(xiii) In order that there will be no misunderstanding of joint and separate duties and obligations to perform work in a safe and pollution free manner, written instructions should be prepared by the owner or operator for contractors and subcontractors to follow whenever contract activities include servicing a well or systems appurtenant to a well or pressure vessel. Such instructions and procedures should be maintained at the offshore production facility. Under certain circumstances and conditions such contractor activities may require the presence at the facility of an authorized representative of the owner or operator who would intervene when necessary to prevent a spill event.

(xiv) All manifolds (headers) should be equipped with check valves on individual flowlines.

(xv) If the shut-in well pressure is greater than the working pressure of the flowline and manifold valves up to and including the header valves associated with that individual flowline, the flowline should be equipped with a high pressure sensing device and shutin valve at the wellhead unless provided with a pressure relief system to prevent over pressuring.

(xvi) All pipelines appurtenant to the facility should be protected from corrosion. Methods used, such as protective coatings or cathodic protection, should be discussed.

(xvii) Sub-marine pipelines appurtenant to the facility should be adequately protected against environmental stresses and other activities such as fishing operations.

(xviii) Sub-marine pipelines appurtenant to the facility should be in good

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operating condition at all times and inspected on a scheduled periodic basis for failures. Such inspections should be documented and maintained at the facility.

(8) *Inspections and records.* Inspections required by this part should be in accordance with written procedures developed for the facility by the owner or operator. These written procedures and a record of the inspections, signed by the appropriate supervisor or inspector, should be made part of the SPCC Plan and maintained for a period of three years.

(9) *Security (excluding oil production facilities).* (i) All plants handling, processing, and storing oil should be fully fenced, and entrance gates should be locked and/or guarded when the plant is not in production or is unattended.

(ii) The master flow and drain valves and any other valves that will permit direct outward flow of the tank's content to the surface should be securely locked in the closed position when in non-operating or non-standby status.

(iii) The starter control on all oil pumps should be locked in the "off" position or located at a site accessible only to authorized personnel when the pumps are in a non-operating or non-standby status.

(iv) The loading/unloading connections of oil pipelines should be securely capped or blank-flanged when not in service or standby service for an extended time. This security practice should also apply to pipelines that are emptied of liquid content either by draining or by inert gas pressure.

(v) Facility lighting should be commensurate with the type and location of the facility. Consideration should be given to: (A) Discovery of spills occurring during hours of darkness, both by operating personnel, if present, and by non-operating personnel (the general public, local police, etc.) and (B) prevention of spills occurring through acts of vandalism.

(10) *Personnel, training and spill prevention procedures.* (i) Owners or operators are responsible for properly instructing their personnel in the operation and maintenance of equipment to prevent the discharges of oil and applicable pollution control laws, rules and regulations.

(ii) Each applicable facility should have a designated person who is accountable for oil spill prevention and who reports to line management.

(iii) Owners or operators should schedule and conduct spill prevention briefings for their operating personnel at intervals frequent enough to assure adequate understanding of the SPCC Plan for that facility. Such briefings should highlight and describe known spill events or failures, malfunctioning components, and recently developed precautionary measures.

APPENDIX

Memorandum of Understanding between the Secretary of Transportation and the Administrator of the Environmental Protection Agency.

SECTION II—DEFINITIONS

The Environmental Protection Agency and the Department of Transportation agree that for the purposes of Executive Order 11548, the term:

(1) "Non-transportation-related onshore and offshore facilities" means:

(A) Fixed onshore and offshore oil well drilling facilities including all equipment and appurtenances related thereto used in drilling operations for exploratory or development wells, but excluding any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(B) Mobile onshore and offshore oil well drilling platforms, barges, trucks, or other mobile facilities including all equipment and appurtenances related thereto when such mobile facilities are fixed in position for the purpose of drilling operations for exploratory or development wells, but excluding any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(C) Fixed onshore and offshore oil production structures, platforms, derricks, and rigs including all equipment and appurtenances related thereto, as well as completed wells and the wellhead separators, oil separators, and storage facilities used in the production of oil, but excluding any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(D) Mobile onshore and offshore oil production facilities including all equipment and appurtenances related thereto as well as completed wells and wellhead equipment, piping from wellheads to oil separators, oil separators, and storage facilities used in the production of oil when such mobile facilities are fixed in position for the purpose of oil production operations, but excluding any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(E) Oil refining facilities including all equipment and appurtenances related thereto as well as in-plant processing units, storage units, piping, drainage systems and waste treatment units used in the refining of oil, but excluding any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(F) Oil storage facilities including all equipment and appurtenances related thereto as well as fixed bulk plant storage, terminal oil storage facilities, consumer storage, pumps and drainage systems used in the storage of oil, but excluding inline or breakout storage tanks needed for the continuous operation of a pipeline system and any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(G) Industrial, commercial, agricultural or public facilities which use and store oil, but excluding any terminal facility, unit or process integrally associated with the handling or transferring of oil in bulk to or from a vessel.

(H) Waste treatment facilities including in-plant pipelines, effluent discharge lines, and storage tanks but excluding waste treatment facilities located on vessels and terminal storage tanks and appurtenances for the reception of oily ballast water or tank washings from vessels and associated systems used for off-loading vessels.

(I) Loading racks, transfer hoses, loading arms and other equipment which are appurtenant to a nontransportation-related facility or terminal facility and which are used to transfer oil in bulk to or from highway vehicles or railroad cars.

(J) Highway vehicles and railroad cars which are used for the transport of oil exclusively within the confines of a nontransportation-related facility and which are not intended to transport oil in interstate or intrastate commerce.

(K) Pipeline systems which are used for the transport of oil exclusively within the confines of a nontransportation-related facility or terminal facility and which are not intended to transport oil in interstate or intrastate commerce, but excluding pipeline systems used to transfer oil in bulk to or from a vessel.

(2) "transportation-related onshore and offshore facilities" means:

(A) Onshore and offshore terminal facilities including transfer hoses, loading arms and other equipment and appurtenances used for the purpose of handling or transferring oil in bulk to or from a vessel as well as storage tanks and appurtenances for the reception of oily ballast water or tank washings from vessels, but excluding terminal waste treatment facilities and terminal oil storage facilities.

(B) Transfer hoses, loading arms and other equipment appurtenant to a non-transportation-related facility which is used to transfer oil in bulk to or from a vessel.

(C) Interstate and intrastate onshore and offshore pipeline systems including pumps and appurtenances related thereto as well as in-line or breakout storage tanks needed for the continuous operation of a pipeline system, and pipelines from onshore and offshore oil production facilities, but excluding onshore and offshore piping from wellheads to oil separators and pipelines which are used for the transport of oil exclusively within the confines of a nontransportation-related facility or terminal facility and which are not intended to transport oil in interstate or intrastate commerce or to transfer oil in bulk to or from a vessel.

(D) Highway vehicles and railroad cars which are used for the transport of oil in interstate or intrastate commerce and the equipment and appurtenances related thereto, and equipment used for the fueling of locomotive units, as well as the rights-of-way on which they operate. Excluded are highway vehicles and railroad cars and motive power used exclusively within the confines of a nontransportation-related facility or terminal facility and which are not intended for use in interstate or intrastate commerce.

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